



GROUP OF SENIOR OFFICIALS ON GLOBAL RESEARCH INFRASTRUCTURES

Case Studies Report

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THE UNDERGROUND LABORATORIES GLOBAL RESEARCH INFRASTRUCTURES

Progress Report on UG GRI Case Study

Prepared for the Group of Senior Officials on Global Research Infrastructures

Executive Summary

In 2012 in Hamburg, the proposal for a world-underground laboratory with the participation of the main operational facilities that fulfil the GSO category of national facilities with global potential, was put forward by Italy that hosts Laboratorio Nazionale del Gran Sasso (LNGS), the largest underground laboratory in operation, also noting that Canada had independently proposed SNOLAB that is the deepest operational underground laboratory. The GSO visited LNGS as part of its 2014 meeting, and the scope of the **Underground Laboratories Global Research Infrastructures-UG GRI** conceptually developed by LNGS and SNOLAB was further discussed. In 2015, the Group of Senior Officials on Global Research Infrastructures selected the UG GRI as one of five case studies in a pilot exercise aiming to investigate and promote various options for international collaboration.

The mission of the UG GRI is to host experiments that require a low background environment, in which the main research topics of the present scientific programme are: neutrino physics with neutrinos naturally produced in the Sun and in Supernova explosions, determination of the neutrino masses in neutrino-less double beta decays; WIMP (Weakly Interacting Massive Particles) dark matter search; and studies of cross sections of nuclear reactions of astrophysical interest. Moreover, the geological characteristics of the Underground Laboratories GRI and the ultra-low background radiation environment they provide, have increased impressively the multidisciplinary science activities including Climate Change research, Geoscience, Biology, Mining Innovation and Environmental Sciences. Since the end of nineteen-eighties the Underground Laboratories GRI are large scale facilities, not limited to the need of one specific

detector for one specific experiment, but rather complex laboratories capable of hosting several – usually international – collaborations and detectors at a given time, spanning on different science fields. These infrastructures are costly in construction and operation and could greatly benefit from a coordinated development of operational standards – security, safety, management of resources and materials – and to further enhance the quality and complementarity of access to the differently specialized sites.

Several medium-size or small-size underground laboratories are operational in the world, and a few new undertakings are planned in the Andes and in Australia and a major upgrade is planned in China.

LNGS and SNOLAB have taken the lead to develop the UG GRI global concept in dialogue with most underground laboratories and with the scope to develop a roadmap towards a full alignment of standards, opportunities for economies of scale in the main technical dimensions, further development of the open access policies and sustainable collaboration at global level towards a global optimization of effort and maximum scientific output.

The readiness of the UG GRI to implement its roadmap, the ongoing expansion of the international membership, the clear objectives of the phase 1 of establishment of the GRI were considered by the GSO as elements of maturity that warrant the **Advanced GRI Project** status that, in turn, will give maximum international visibility to the project creating most favourable conditions for its successful implementation.

Introduction

The mission of the Underground Laboratories is to host experiments that require a low background environment, in which the main research topics of the present scientific programme are: neutrino physics with neutrinos naturally produced in the Sun and in Supernova explosions, determination of the neutrino masses in neutrinoless double beta decays, WIMP (Weakly Interacting Massive Particles) dark matter search, and studies of cross sections of nuclear reactions of astrophysical interest.

Moreover, the geological characteristics of the Underground Laboratories and the ultra-low background radiation environment they provide, have increased impressively the multidisciplinary science activities: Climate change research, Geoscience, Biology, Mining Innovation and Environmental Sciences.

Until the mid eighties most underground sites were tailored around specific (large) detectors. Then LNGS was constructed as the world's

first general purpose large underground research facility. The LNGS underground laboratory (about 1400 metres deep) consists of three large halls, which host the largest detectors, connected by access and ancillary tunnels, which host smaller experiments and service infrastructures. LNGS is presently the world's largest operational underground research facility. Access to experimental halls is horizontal and it is facilitated by a highway tunnel.

About 15 years after LNGS, another world-class underground facility, SNOLAB, has been realized in Canada in an operating nickel mine near Sudbury, Ontario. SNOLAB is deeper than LNGS (about 2000 metres deep), although accessible by vertical shaft only, using mine-supported elevator cages. Two additional large underground facilities are operational: SURF (Homestake, SD) in the USA and CJPL (Jinping,

Sichuan) in China. An upgrade to CJPL-II will ultimately be larger than LNGS and deeper than SNOLAB.

The European Deep Underground Research Infrastructures are represented by: Laboratoire Souterrain de Modane (LSM, France), Laboratorio Subteraneo de Canfranc (LSC, Spain), Boulby Underground Laboratory (Boulby, United Kingdom) and CallioLab in Pyhäsalmi mine (Finland).

Two other underground laboratories are in development: one in the Andes between Argentina and Chile, another one is Stawell Underground Laboratory in Australia, which is considered a medium-size underground facility under construction.

	LNGS	LSM	LSC	BUL	CLAB	SNOLAB
Date of Creation	1987	1982	2010	1989	1995	1991
Surface m²	18 000	500	1 600	500 + 1 000	2 000	5 000
Volume m³	180 000	3 500	11 000	4 000	10 000	37 000
Personnel	95	13	11	6	13	75
No of users	950	150	240	70	30	485
Depth (mwe)	3 700	4 800	2 450	2 800	4 000	6 000
Altitude	1 000	1 240	1 195	- 1 000	- 1 400	1 140
Muon flux/(m².s⁻¹)	2.87 * 10 ⁻⁴	4.6 * 10 ⁻⁵	2-4 * 10 ⁻³	4.1 10 ⁻⁴	1.1 10 ⁻⁴	3 * 10 ⁻⁶
[Radon] Bq/m³	20 - 120	10 - 15	70	< 3	< 70	130
γ -ray flux/ (m².s⁻¹)	0.3 - 1 * 10 ⁴	3.8 * 10 ⁴	1.23 ± 0.17 10 ⁴	~1.3 * 10 ⁴	-	-
neutron flux / (m².s⁻¹)	~3.78 * 10 ⁻²	(1.1 ± 0.6) * 10 ⁻²	3.47 ± 0.35 10 ⁻²	< 1.5 * 10 ⁻²	-	4.6 * 10 ⁻²
Access	Horizontal	Horizontal	Horizontal	Vertical	Hor. -Vert.	Horizontal

Table 1: Features of LNGS, SNOLAB and European Deep Underground Laboratories

The LNGS annual operational cost (materials, maintenance and energy) is set at 8.1ME for 2016 and 10.6ME for 2017. The total construction cost (infrastructures, plants, equipment) of the scientific projects (considering the large and medium scale experiments, today in operation) has a value of 110.3ME. The total annual operational cost of the experiments is 1.8ME.

The SNOLAB annual operating costs (materials, maintenance and energy) are set at CAD\$11 Million for 2016/2017, CAD\$14.5 Million for 2017/2018 and CAD\$15 Million for 2018/2019. The total infrastructure cost of SNO and SNOLAB totals CAD\$180 Million. The experimental costs are borne by experimental groups; services offered by SNOLAB are determined before installation through an MoU.

Rationale for Inclusion among GSO Case Studies

In order to implement a more coherent underground RIs strategy and vision a core mechanism is proposed. The goal foreseen is to facilitate networking and information exchange between the underground laboratories that exist world-wide and share common challenges:

a) Robust experiment assignment protocols

The proposed GRI strives to firstly develop an agreement on standards of practice in the procedures and mechanisms used to introduce and assess new science and users to the laboratories. This area will start by comparing in detail the existing practices of the scientific advisory

committees of each RI. The aim is to formulate a strategy for **common access procedure** including the preparation of experimental proposal at different stage (Expression of Interest, Letter of Intent, Conceptual Design Report, Technical Design Report), and once approved the monitoring of the project progress (installation, commissioning, operations) and scientific results (leading to final decommissioning).

b) Common Safety and Risk assessment guidelines

Even if access to the RIs is currently governed by safety rules formulated according to the different locations of the labs (tunnel or mine) and local/national laws, it is thought to be possible and useful to define **common user guidelines**, which will ensure users' safety while inside the labs, the safety of the labs themselves, etc. Safety, here widely meaning Environmental, Safety of Equipment, Health and Safety (EH&S) subject, is a common issue for all RIs.

The past and present experiences on safety from each laboratory will be used to propose recommendations for the safety in the future infrastructures, improve best practice concerning the safety in underground laboratories and give recommendations for extensions or new cavities. The approach will be based on an engineered methodology standard, such as the implementing of safety guidelines for all the structures and description and implementation of a Safety Management System, devoted to each of the RIs.

EH&S reviews and assessments will include analyses of: normal operation; maintenance; incidents and accident scenarios; handling and storage of materials; commissioning and test operation; and decommissioning. The results of these analyses will be available to assist the preparation of documentation for regulatory applications.

c) Maintenance and continuous upgrade

As the RI's age, more regular maintenance will be required which will need to be included in budgets and may require additional staff. Also, as experimental programmes evolve, the RI's may demonstrate a need for additional or larger cavity space for bigger experiments.

d) Human resource management of permanent staff

Attraction of qualified science staff and HQP can be difficult due to location and ability to provide a suitable academic culture and

environment; there is a best practice at the RI's that can be taken advantage of to help with this process.

e) Share and Spread Best Practices

Develop **protocols and methods** for open access within the network to specific technological facilities: gamma and mass spectrometers, electro-forming facilities, etc.

Environmental radiation abatement, materials screening in facility construction, radon abatement system and procedures can form a template for a **coherent and coordinated development** among RIs.

f) Transnational access

A framework based on an easy sharing of capabilities and services; to meet specific needs of the scientific communities that require an underground environment, particularly for new users. One of the main objectives is therefore to give **access to measurements at a wider range of underground installations, increasing the analytical power of underground science**. The overall effect of a TA program will be to open coherently the RIs to researchers who need **data exchange and interoperability**.

g) Global open innovation

The integration of RIs is an opportunity to organise ideas and information exchanges to create an innovation environment to provide frontier services to frontier research:

- Internalisation - invite innovative projects carried out by industries to use the unique facilities provided by the RIs.
- Externalisation - transfer of innovations and knowhow to stakeholders (e.g. innovative techniques for identifying trace elements and for new generations of highly sensitive radiation detectors).
- Building a platform with a wide range of domains in science and technology to support job creation.

Rationale for a Leading Role of LNGS and SNOLAB

The distributed Underground-GRI shall include more partners, but could already provide a reference of standards and best practices at an initial limited partnership, but with the clear goal of growing to the global dimension. There is a strong rationale for exploring this possibility as each underground laboratory has its own peculiarities (size, depth, background, access, complementary specialized infrastructure). The access policy could be progressively integrated at GRI level allowing for optimal strategy of the experiments (that are already quite international) and **optimal upgrade/specialization of each partner facility**, whilst maintaining

the natural and healthy scientific competition and competition in improving each facility.

LNGS

The surface facility is located on a 130.000 m² area on the L'Aquila side of Gran Sasso massif. It comprises the headquarters and the support facilities including the general electric and safety service, computing and networking services, mechanical, electronic and chemical workshops, clean room with Inductively Coupled Plasma

Mass Spectrometer (ICP-MS), halls for assembling and testing large equipment, offices, administration department, library, meeting halls and canteen. Currently LNGS staff consists of 95 people, the scientific users of LNGS amount to about 1000 per year, one quarter of whom are working there on any given day, while many others are offsite analysing data or preparing new experiments.

Underground Halls are equipped with all technical and safety equipment and plants required in order to run large and complex experiments and to ensure proper working conditions. Today the Gran Sasso Labs are equipped with fully active Safety Management System and Environmental Management System.

The 1400 metre-rock thickness above the Laboratory represents a natural coverage that provides a cosmic ray flux reduction by one million times. The permeability of cosmic radiation provided by the rock coverage together with the huge dimensions and the impressive basic infrastructure make the Laboratory unmatched in the detection of weak or rare signal which are relevant for astroparticle, sub nuclear and nuclear physics.

The Mission of the Laboratory is to host experiments that require a low background environment, the main research topics of the present scientific programme are: Neutrino Physics with neutrinos naturally produced in the Sun and in Supernova explosion, search for neutrino mass in Neutrinoless Double Beta Decays, Dark Matter search, Nuclear Reactions of astrophysical interest, associate sciences including Environmental Radioactivity for Earth Sciences, Geophysics, Fundamental Physics, Biology.

Excellence of the LNGS is an ultra-low level radioactive counting facility, to test materials for 3rd generation experiment. Many different technologies and detectors are optimized and used: Liquid and Plastic scintillators, Noble liquid TPC, Nuclear Emulsions, Ultra High-Purity Germanium detectors, TeO₂ Bolometer detectors, Scintillating bolometers, extremely radio-pure NaI(Tl) scintillators.

The scientific activity of LNGS is in extremely exciting period for the quality and richness of the experiments, all amongst the most competitive worldwide. The already approved experiments are in different phases of developments and the temporal horizons of their activity extend on different duration. Their scientific objectives will be fully reached in time intervals ranging from several years up to the end of the decade. At the present, LNGS holds the leadership in experiments with the highest performance in the low background levels.

An important meeting was held in April 2015 to launch "LNGS – 2020 and Beyond," a framework for selecting future experiments and performing the necessary R&D. A subsequent call for requests for resources confirmed that the demand for space underground and for other resources exceeds what is available.

Access to LNGS is granted on the basis of scientific excellence. An international Scientific Committee, which meets twice per year,

scrutinize scientific proposals, formulates recommendations for approval of experiments, and monitors their progress.

LNGS plays a most important role in supporting the innovation in the Abruzzo region. It is a hub for innovation, internally and in Tech Transfer partnerships with regional enterprises, and serves as a major centre for outreach and education attracting 8000 visitors/year.

SNOLAB

SNOLAB is an International Facility for Underground Science; it is an expansion of the original facilities constructed for the Sudbury Neutrino Observatory (SNO) solar neutrino experiment. The primary focus of the science programme includes solar neutrinos, supernova neutrinos, neutrino-less double beta decay and dark matter searches. SNOLAB supports eight projects covering these research fields, including various aspects of the dark matter interaction parameter space, and both neutrino source and intrinsic physics studies. Projects range in size up to kiloton detectors.

While particle astrophysics is the principle focus for SNOLAB, there is a growing interest in other scientific fields to exploit deep underground laboratories and their associated infrastructure. In particular, there have been growing developments in the fields of mining innovation, where SNOLAB supports data analytics for mining innovation, and biology/genetics, where SNOLAB supports projects studying the impact of underground low radiation environments on biological systems.

The great depth at which SNOLAB is located is required to shield these sensitive detection systems from the ubiquitous cosmic radiations that bombard the surface of the planet. By placing 2km (6000m water equivalent) of rock between the detectors and the surface these cosmic rays are sufficiently attenuated, by a factor of 50 million down to one cosmic ray muon every day per 4m², that the rare and exquisite signals from the science of interest can be separated from the signatures from other backgrounds.

The current mission of SNOLAB, in line with its vision, is to:

- **Enable** world-class science to be performed at SNOLAB by national and international experimental collaborations, providing scientific underpin, technical skills and knowledge, generating and developing international connections, and through development of a strong reputation; SNOLAB will also provide risk mitigation, reacting quickly to challenges/crises to enable the efficient execution of the scientific programme.
- **Spearhead** world-class science at SNOLAB through its own research group as part of the international and national community, developing synergies with other groups worldwide.
- **Catalyze** world-class science at SNOLAB by providing a sought after collaborator in its own right and through providing transformational opportunities for collaboration and knowledge exchange to

other groups through workshops, external connections and local interactions.

- **Promote** world-class science and societal benefits through a strong public and professional outreach programme, and through technical knowledge development and transfer.
- **Inspire** the next generation of innovators through strong educational outreach, knowledge transfer and the training of highly qualified personnel.

The facility includes a surface building which houses offices, conference rooms, IT systems, clean-rooms, electronics labs, warehousing and change rooms. The underground facility is located

at a depth of 2070m and comprises 5000m² of clean room facility, at better than Class2000, including three large detector cavities. In addition to the required health and safety systems and user support services, support infrastructure for experiments within the underground laboratory include HVAC, electrical power, ultra-pure water, compressed air, radiological source control, radio-assay capability, chemistry lab, I.T. and networking, and materials handling and transportation. The very specific requirements of developing and operating experiments in an underground laboratory are supported by a staff of ~80 covering business processes, engineering design, construction, installation, technical support and operations. The SNOLAB scientific research group connects to the experiments and provides expert and local support, as well as undertaking research in its own right as full members of the research collaborations.

Governance

The coordination will concern all the facility aspects and will realize an overall optimization of the cost and human resources involved in the operation and support of the facilities, not interfering with scientific competition and freedom.

Currently, the operation of the Underground Infrastructures relies entirely on national or regional or academic funds and include costly services and scientific, technical and support staff as well as substantial safety systems. The experiments exploiting the Underground Infrastructure are funded by Research Institutions and Research Funding Agencies often in the framework of international collaborations with variable geometries, in-kind contributions etc. There is no charge for access to the underground RIs. Most services and facilities (workshops, material screening, electricity, etc.) are supplied for free to the experiments. There are potential economic advantages in the standardizations listed above, if they can be effectively enforced at GRI level. But there is a quite higher potential in regulating at GRI level the cost management of the infrastructures as a key ingredient of the experiments budget.

A light governance structure will serve the Phase-1 with a council that will meet three times a year with ancillary meeting. Two levels of reviews are necessary:

- a) internal reviews carried by the GRI on individual RIs;
- b) external reviews carried by a panel of independent experts on the GRI.

A strong support from GSO is required to drive the variety of interested RI towards a framework agreement for a Phase-1 to GRI: network of collaborating RI; to help in identifying legal support for agreements on IP, technology transfer, etc. (multilateral light agreement to start with, or several bilateral concurrent agreements if easier); to monitor the progress of the GRI, stimulate and contribute to the definition of a roadmap towards a Phase-2 of higher integration.

G8+5 or G7 ministerial could give explicit support to the advanced exploration of the Underground-GRI and this could give high visibility to the undertaking and set a favourable stage for financing the necessary integration activities by national resources as well as European and international agreements

Development of a Roadmap towards higher Integration

GRI roadmaps should define the priorities, clear articulation of the RI needs, strong alignment between the research agenda, and the provision of infrastructure, joint planning to include RI in full cycle of GRI development. The GRI looks into launching an Integrating Activity, to produce a real step-change in the breadth, quality and integration of service to the users. The scope is to **pool detailed experience of working methods across the laboratories**, hence to spread and develop best practice in the details of the coordination and running of underground science programmes. In parallel, it plans

a **common development of key technologies capable to increase substantially the discovery potential** of the searches performed currently or in prospect of distributed infrastructure collecting top-class underground facilities, with shared approaches to the management of the laboratories, the coordination of the science programmes, the scientific advisory procedures, and the development of vital R&D projects. The RIs span a wide range of environmental conditions and so can offer the user an exceptional range of complementary characteristics, for instance in size, depth, rock

composition, radiation, geological, seismic and hydrologic conditions. In the phase-1 the GRI promote and enhance the coordination needs and exciting scientific prospects of the RIs, addressing the following Working Packages:

- *WP1 Coordination of the Research Areas*

Structure and unify the related communities and establish links between nearby research sectors. Constitute a forum to connect the potential of underground infrastructures to other sectors of science and technology (like geosciences, biology, environmental sciences, climate science).

Establish and reinforce links with the industrial sectors connected to the low radioactivity environment and screening materials (like biotechnology, nanotechnology, semiconductor and electronics industries).

- *WP2 Quality assurance and best practice*

Protocols for safety and operational in installing, commissioning and operating large detectors (10 m, few kton scale) in deep underground research facilities: to prepare white book of best practices for safety rules, personnel and users training procedures, access protocol,

emergency response protocols and training exercises, environment management, list of dangerous materials and their suggested replacement.

Provide key elements to assess the opportunity to build new facilities and to carry on new excavations

- *WP3 Innovation Policy*

Provide a well-controlled environment to test novel technologies (Gamma Spectrometry, Micro/Nano Electronics, Photonics, Scintillators, Cryogenics, etc.) promoting an industrial collaboration through highly-trained engineers and scientists.

Thanks to this implementation structure the users will have access to better-organized and more efficient infrastructures, to well structured and non-redundant databases with results relevant for their research. The international community will have the chance to better plan of future research, singling out the most promising and assuring optimal use of the infrastructures where the research is performed. The overall effect will be a **strong enhancement of the organisation and efficiency of the underground infrastructures as a whole**, helping to guarantee their sustainability and competitiveness.

Progress in the Global Dialogue for Defining the Underground GRI

Since site visit in 2014, since last GSO in 2016

The dialogue was started by LNGS (I) and SNOLAB (CAN) on a conceptual design of a Global Underground Research Infrastructure that could harmonize the best practices of the participants, set standards on the relevant safety and infrastructure management and on data management, archiving and open access.

The overall goal is to build a reference global infrastructure for underground science that will serve the scientific community of the world and that could accommodate in an efficient manner the needs of new experiments and the planning of novel upgrades and needs.

The proposed GRI is in close contact with different countries in the European Research Area such as UK, France, Spain, Finland, Germany, and established contacts with scientific communities of Argentina, Africa and Australia.

EUROPE

The largest number of underground infrastructures is in Europe, present both in the Western and Eastern parts. The small and middle size European Deep Underground Laboratory (DUL): LSC (Spain), LSM (France), Boulby (UK), Pyhäsalmi (Finland), will have very valuable contribution in the Global Infrastructure for Deep Underground Science. The activities of these laboratories are fully complementary with Large DUL for fundamental physics (R&D in particle, astroparticle and nuclear physics) and interdisciplinary research. The site location and characteristics highly enhance the capability and the diversity of interdisciplinary science. All the DUL have common aims to develop low radioactive measurements and assay, and associated material

development techniques. Exchanges at the global level will profit to all of them and could be a way to make a breakthrough in this field. Moreover, all the DUL are performing measurements for material screening with very low radioactivity gamma-ray spectrometers and the perspective to collaborate at the global level will increase considerably the capabilities of measurements. The advantages of small and medium size laboratories in allowing connections with local and regional communities requiring access to DUL, and allowing the development of Deep Underground Science. These laboratories also play an important role in the education of young scientists in the Deep Underground Science community.

Expression of interest in joining UG GRI has been established with LSC, LSM, Boulby, Pyhäsalmi with formal letters attached.

GERMANY: an action is in progress.

RUSSIA

BNO, Baksan Neutrino Observatory (Russia) an action is in progress.

AUSTRALIA

Stawell Underground Laboratory (SUPL) Australia.

A collaboration agreement has already been established for an experiment to be run simultaneously in LNGS and Stawell. An action is in progress, with a very positive feedback, a formal letter of interest is attached.

SOUTH AMERICA

ARGENTINA: ANDES (Agua Negra Deep Experimental Site), formal expression of interest by Prof. Dr. Alejandro Ceccatto, President of CONICET is presented.

SOUTH AFRICA

Actions are in progress.

ASIA

CHINA

Following a visit to LNGS by a delegation of CJPL, the LNGS Director, Stefano Ragazzi will travel to China to exploit collaboration opportunities between CJPL and LNGS in April 2017. He will take advantage of the visit to invite CJPL to join the UG GRI.

Intended Outcomes

Main benefits of the Underground-GRI.

Benefits for new infrastructures

New underground infrastructures of small to medium size that are planned worldwide will take great advantage from the shared expertise at GRI level, as the proposers LNGS and SNOLAB and other potential partners have a track record of several years of operation with large complex experiments; they will also benefit of access to highly specialized facilities (e.g. material screening) run by the larger laboratories, with the possibility to stage investments over several years. This will result in major economic benefits with the optimization of infrastructure and facilities performance versus investment. (for instance: a poor choice of construction materials would result in a higher radioactive background requiring larger shielding for detectors, higher air exchange rate for radon abatement, thus higher investments for experiments and facilities and higher

operating costs; these extra costs, or loss of performance, can be up to 50% of the value of a sensitive gamma spectrometer).

Benefits for existing infrastructures

The need to exchange, compare, and transfer expertise will stimulate existing facilities to improve quality and process controls, and extend documentation and databases; this will help to root unique skills in the infrastructure and make them ready for transfer to society. The adoption of best practices, standards, and protocols will greatly improve the development, construction, operation and management of large experiments, and provide beneficial information exchange for facility operations and management. It will also stimulate the definition of standards to implement open access to data.

Interest in joining a distributed GRI has been expressed by several facilities, see table I, of different size and scientific reach, at different stages of development, that span the entire range from project to fully operating (and mature) facilities.

Work Allocation

Funds are needed on the short term to support:

- Three persons fully devoted to support and organize.
- The documentation for the feasibility study and draft the technical design study of the GRI.
- Temporary mobility of scientific and technical personnel concurring to the GRI project.

- Topical and general meetings and joint initiatives.

Alignment of UG GRI Case Study with GSO Framework Criteria

UG GRI aligns with the GSO Framework Criteria as follows:

1. Core purpose of global research infrastructures

The core purpose is frontier research in the domains of Astroparticle Physics that require high shielding capability from external radiation and extremely radio-pure materials. It also includes frontier training in science and technology with two main goals: a) consolidate in a

large infrastructure key enabling techniques; b) improve transfer of knowledge and technology to society.

2. Defining project partnerships for effective management

Agreements for partnership are still to be defined.

3. Defining scope, schedule, and cost

Partly applies to the proposed GRI. Direct costs are those connected to networking activities. They are minor costs with respect to the costs of implementation and/or running the individual infrastructures.

4. Project management

The proposed Phase-1 will address the spread and review of best practices, including management, to prepare the RIs to a grater integration in a second phase.

5. Funding management

Same as Project management

6. Periodic reviews

Two levels of reviews are necessary: a) internal reviews carried by the GRI on individual RIs; b) external reviews carried by a panel of independent experts on the GRI. These are common practices applied by Funding Agencies and Research Institutions to LNGS and SNOLAB and can be easily extended to the GRI.

7. Termination or decommissioning

It is not applicable to a distributed GRI made by RIs that would exist outside the GRI. A termination date should exist for agreements with allowance for extensions/renewals.

8. Access based on merit review

Access based on merit has to be a founding principle of the GRI. However the criteria adopted by LNGS and SNOLAB cannot be plainly extended to infrastructures at every scale. A progressive development of a single entry point for access proposals to the GRI is to be developed and should be based on an international liaison panel that evaluates the optimal location for the requested access and the related implications at technical and economic level.

9. E-infrastructure

Data management principles adopted at large scale infrastructures could be aligned at GRI level and create the basis for a global

repository of underground science data with appropriate data standards, giving open access to data and securing long term data preservation, interface to the external data networks, access to high throughput and high power computing at global level.

10. Data exchange

It is not yet a common practice in the research domain addressed. Standards will have to be defined and implemented for effective access to data. Support from e-infrastructures and collaboration with initiatives in the nearby domains of nuclear and particle physics should be foreseen.

11. Clustering of research infrastructures

Skills and experience have been developed, independently in the RIs, the clustering aims to improve the innovation capacity, to provide a strategy to compare access procedures and safety protocols in order to develop best practices, which should become homogeneous, while taking into account the operational differences and legal statuses, to enhance the organization and efficiency of the underground RIs helping to guarantee their sustainability and competitiveness.

12. International mobility

Mobility of scientific and technical personnel will be one of the main instruments to achieve effective spread of best practices and effective integration of activities.

The overall effect of the international mobility will be to open coherently the GRI to researchers who need an underground environment, beyond the framework offered by national funding agencies and therefore extending and fully realizing the potential of the underground infrastructures in terms of scientific research and of industrial impact.

13. Technology transfer and intellectual property

Fully subscribe to the GSO statement.

14. Monitoring socio-economic impact

Alignment with the general effort to evaluate impact of the Research Infrastructure will be done with reference to the GSO, GSF and local exercises done e.g. by ESFRI.

THE INTERNATIONAL MOUSE PHENOTYPING CONSORTIUM GLOBAL RESEARCH INFRASTRUCTURE

Progress Report on IMPC Case Study

Prepared for the Group of Senior Officials on Global Research Infrastructures

Executive Summary

The **International Mouse Phenotyping Consortium Global Research Infrastructures-IMPC GRI** addresses one of the grand challenges for biology and biomedical science in the 21st century – to determine the function of all the genes in the human genome and their role in disease. The bold goal of the IMPC of creating an encyclopaedia of mammalian gene function will require the support, infrastructures and cooperation of multiple countries. By the beginning of 2017, the IMPC had generated over 6,000 mouse mutant lines and phenotyped nearly 5,000 lines. These mouse strains are characterized using a standardized, broad-based biological and physiological analysis platform, in which data are collected and archived centrally by the IMPC-Data Coordinating Centre. The data are uploaded in standardized formats, checked for data quality and completeness by the DCC before release to the public database.

The IMPC, at present, operates as a distributed global research infrastructure comprised of 19 research institutions and 5 national funders, representing 13 countries from 4 continents and has been in operation since 2011. There is no centralized funding for the IMPC, but each center must generate financial support for the project from local, national and international funding agencies. The consortium is managed by a Steering Committee (SC) comprised of all members and overseen by the Chair of the SC and an Executive Director. The groups adhere to a non-legally binding Governance Document that defines project interactions, goals, operations and expectations.

The next stage for the IMPC to implement a Global Research Infrastructure according to the Framework criteria will be crucial for the science project and for the full internationalization of the effort to increase the production and phenotyping level. As of today the IMPC has reached a critical mass of members and its organization has reached maturity, but the overall financial effort has not gone beyond our Phase 1. A Phase 2 with more members and an increase of contribution by the current Phase 1 members is the crucial goal of IMPC GRI to enable the necessary increase in both quantity and diversity of phenotyping tests. The GSO Case Study exercise has already helped the IMPC gain a new member in South Africa. The GRI status will facilitate the recruitment of new members, focusing on India and China. The IMPC GRI will develop on the strong basis that is represented by the IMPC centers that insofar all became key

reference centers at national level for mouse genetics and functional genomics, and provide centres of national expertise and resources.

The implementation of the GRI with the support of the GSO and, possibly, of G7 will set the basis for a full international status of IMPC which, in turn, would help the national centers continue to garner political and financial support for their efforts. We envision that the IMPC will serve as a resource to work with precision medicine initiatives to rapidly create mouse models and confirm human disease correlations. It is imperative that IMPC keep its momentum and recognition as a global infrastructure to develop and support these rapidly advancing projects. The IMPC can serve as a focal point of these converging areas of research, and facilitate machine learning across expanding mouse and human data sets. The potential impact on human disease understanding is enormous. Furthermore, the recognition of the IMPC as a GRI, will help secure IMPC's position as a resource infrastructure for future large-scale projects to utilize the IMPC and not build again. We envision several new "super projects" that would utilize the IMPC platform. One such example would be large-scale humanization projects of biochemical and druggable target pathways to create not just more relevant disease models but also interface with industry to facilitate pharmaceutical development. The upgrade of IMPC as a GRI would help preserve this valuable infrastructure that would be difficult to recreate and will also set a high standard on data quality of advanced research results, at the frontiers of knowledge, that will contribute to the richness and trust of the open data policies at the global level.

The readiness of the IMPC GRI to upgrade at the GRI level, its ongoing expansion of the international membership, the effective operational level already reached in its first stage, were considered by the GSO as elements of maturity that warrant the **Advanced GRI Project** status that, in turn, will give maximum international visibility to the project creating most favourable conditions for its successful implementation.

Introduction

The IMPC is a confederation of international mouse phenotyping projects working towards the agreed goals of the consortium to undertake the phenotyping of 20,000 mouse mutants over a ten-year period, in two distinct Phases, providing the first functional annotation of a mammalian genome. The IMPC Steering Committee provides the governance for the overall consortium. Participants are tasked with making key strategic decisions including selection of participating organizations, approving and coordinating key operational decisions such as phenotyping platforms and pipeline used, quality assurance and operating standards, and IT organization. Membership provides stakeholders with an opportunity to influence key activities as they develop.

The International Mouse Phenotyping Consortium (IMPC) emerged from the work and successes of several preceding programs, including the International Knockout Mouse Consortium (IKMC). The IKMC, formed in 2005, set out to deliver a mutant ES cell line for every gene in the mouse genome¹. The success of the IKMC and emerging world-wide phenotyping efforts including those of the Wellcome Trust Sanger Institute Mouse Genetics Program (WTSI MGP²) and

the European Mouse Disease Clinic (EUMODIC) program³, the first internationally coordinated large-scale phenotyping effort funded by the European Commission (EC), led to much discussion regarding the possibility of a coordinated international program in mouse phenotyping.

The current IMPC is comprised of 19 research centers based in 13 countries, spanning North America, Europe, Africa, Asia and Australia. The IMPC also has 5 funding body who are members of the Steering Committee. By the launch of Phase 2 at the end of 2016, the IMPC had generated over 6,000 mouse mutant lines and phenotyped nearly 5,000. All phenotype data is available via the IMPC web portal (www.mousephenotype.org), which provides the community with diverse points of entry to search the data based on gene, phenotype, and relationship to human disease. The pace of mouse production and phenotyping continues in Phase 2 of the program, and by the end of 2017 we expect to have generated mutant lines and completed phenotyping for one-third of the mouse genome.



Summary of Main Achievements

since the previous Report

Over the past six months the IMPC completed Phase 1 of the project in October of 2016 and launched Phase 2. The IMPC has added one new member from China, Soochow University, and is working closely with Professor Anne Grobler of North-West University, Potchefstroom South Africa to help their entry to the IMPC. Scientifically, the IMPC has several major publications in submission based on the dataset;

these are involved in metabolic disease, sexual dimorphism in research, eye disease, deafness and human disease traits.

Analyses of the IMPC dataset are transforming our understanding of the mammalian genetic landscape. Several major studies of the IMPC datasets have been performed that reveal novel and unexpected features of the mammalian genome and highlight the extraordinary

1. Skarnes et al. (2011) A conditional knockout resource for the genome-wide study of mouse gene function. *Nature* **474**: 337–342

2. White et al. (2013) Genome-wide generation and systematic phenotyping of knockout mice reveals new roles for many genes. *Cell* **154**: 452–64.

3. Hrabe et al. (2015) Analysis of mammalian gene function through broad-based phenotypic screens across a consortium of mouse clinics. *Nature Genetics* **47**: 969–978.

utility of the data and the resource created. Overall, the IMPC data supports broad-ranging opportunities to develop new insights into biological and disease mechanisms.

Objectives

- **Maintain and expand a world-wide consortium of institutions** with capacity and expertise to produce germ line transmission of targeted knockout mutations in embryonic stem cells for 20,000 known and predicted mouse genes.
- **Test each mutant mouse line** through a broad based primary phenotyping pipeline in all the major adult organ systems and most areas of major human disease.
- Through this activity and employing data annotation tools, systematically **aim to discover and ascribe biological function to each gene**, driving new ideas and underpinning future research into biological systems.
- **Maintain and expand collaborative “networks”** with specialist phenotyping consortia or laboratories, providing standardized secondary level phenotyping that enriches the primary dataset, and end-user, project specific tertiary level phenotyping that adds value to the mammalian gene functional annotation and fosters hypothesis driven research.
- Provide a **centralized data center and portal for free**, unrestricted access to primary and secondary data by the scientific community, promoting sharing of data, genotype-phenotype annotation, standard operating protocols, and the development of open source data analysis tools.
- Members of the IMPC may include research centers, funding organizations and corporations.

IMPC Expansion of International Collaboration and Partnerships

The involvement of the IMPC with the GSO has been beneficial on several fronts, including shared knowledge and experience, but also helping the IMPC with expanding its message. The recognition by the GSO has already helped elevate the recognition of the IMPC and hopefully will increase awareness and foster new opportunities for expansion with other countries to join the IMPC effort. The IMPC has given much consideration to a more structured legal entity for the organization to facilitate expansion, but that approach has met with several nearly insurmountable obstacles that are related to the IMPC’s inherent structures. Firstly, the IMPC does not have a single physical site in a single country—the presence of a single site simplifies the legal structure. In cases of a single physical structure, it is possible to solicit funds from countries that plan to use the facility to aid in the construction. The IMPC has sites in 13 countries, including Europe, North America, Australia, 4 sites in Asia and soon in South Africa. Each site has multiple purposes and were not built solely for the IMPC. Secondly, each center obtains funding from local and national sources. Since there is not a pre-existing legal structure that could tie together all the various physical sites, and as funds are related to each local project, it is not likely that funds could be co-

mingled. Going forward, it would be ideal for funding agencies to set aside funds for the IMPC that could be distributed to members to help complete the project. It is highly likely that even this would take on a regional bias for awards but would still help fund the overall project.

Since our last report, the IMPC has moved forward with expansion which has included contacts with Professor Ying Xu from **Soochow University, Suzhou China**. This group completed the application and review process in less than 6 months is now a member of the IMPC. Soochow University will co-host the next IMPC meeting May 9-12, 2016 in China to launch their formal membership. Interactions with the GSO has led to a rapid dialogue with South African research groups, and their likely inclusion in the IMPC during 2017. Dr. Daniel Adams introduced the IMPC to Professor Anne Grobler of the **North-West University, Potchefstroom, South Africa**. The IMPC sent a team to site visit the University facility in October 2016 and discussed possible membership. We anticipate a membership application submission in the next several weeks and the likely inclusion of this group to the IMPC in mid-2017.

Procedure for Expanding International Collaboration and Partnerships

The IMPC procedure for expansion begins with discussion with researchers who have a scientific interest in becoming part of the IMPC. In most instances these investigators are already

affiliated with modern state of the art animal research facilities and seek new projects and funding to work in the existing infrastructure. The investigator then discusses with the IMPC possible research

interactions and projects that could be integrated with the IMPC and how to implement such a plan. The investigator is responsible to secure funding for the project but the IMPC will assist with documentation and data support as needed. The investigator then makes a formal application to the IMPC Steering Committee to join the IMPC and must follow the following Guidelines:

INSTITUTIONAL MEMBERSHIP

1. A track record of experience in high throughput phenotyping and/or large-scale knockout mouse production, allied to the physical resources to undertake such activities, or expertise in specialized ("Secondary level") phenotyping that would add value to the resource and database.
2. For phenotyping centers, a commitment to phenotype not less than 50 lines per year, preferably rising to 100 lines per year within the lifetime of Phase I of the IMPC program.
3. For Secondary level phenotyping groups, a commitment to share data with the IMPC as a whole, and deposit the data into the IMPC Database in a timely fashion.

4. Agreement to work within the framework of the consortium, including commonly agreed phenotyping pipelines and IT structures.

5. Demonstrable ability to provide the IT infrastructure for the local capture of production and/or phenotyping data and its upload to the IMPC data coordination center(s).

6. Agreement to the full release of data to data coordination centers according to IMPC agreed procedures and timelines.

7. Agreement of production centers to provide the community access to live mice, embryos and sperm as soon as possible without intended hold backs, subject to legal or MTA restrictions.

8. Payment of the membership fee of \$100,000 CANADIAN.

The Application is reviewed by the Executive Director and Chair of the Steering Committee for comments and revisions. The Final Application is presented to the entire Steering Committee. To Date some applications have been differed for further development or awaiting funding, but ultimately all have been approved by unanimous consent.

Future efforts and Challenges

It is imperative for the IMPC to leverage the existing alliance of Global Mouse Research Infrastructures to seek additional funding to complete the first major project: a phenotype profile for a KO mouse for every gene in the genome. It is also critical for the IMPC to seek and plan collaborations for new projects to leverage the special expertise and critical mass that has been built through this collaborative effort. As part of this, the IMPC is seeking projects to leverage mouse work with the vast amount of data related to human disease that is being developed through large scale sequencing efforts. Over the next year, the IMPC will work with human genetics groups to identify potential areas and projects of mutual interest and develop strategies and work plans to seek funding for these projects. In such projects, it will be important to obtain buy-in from funding agencies and coordinate funding calls with project timelines. Nearly all IMPC centers have the ability to expand capacity for minimal

additional costs to the physical plant, but would just need an increase in personnel and expendable materials.

Another challenge for the IMPC is long-term sustainability of the data and database that has been developed. Thus far, all data coordination has been funded solely by the NIH (USA) and as the IMPC has expanded there is a need for additional funding to support new centers that come online as well as plan for the long-term data warehousing. These issues need to be addressed in the next 5-year phase of the IMPC which began October 2016.

Best Practice: Quality Control, Data Management and Access Policy

The development and use of comprehensive and standardized phenotyping protocols (SOPs) are vital to ensure data quality across the consortium. Effective SOPs ensure that results are comparable within and between different laboratories and over time and are also essential in relating phenotypic data to ontological descriptions in any automatic annotation pipeline. An additional challenge regarding data integration from multiple centers is the requirement to interact with diverse LIMS and instrumentation. The

inherent high complexity of phenotype data produces a requirement for standardizing meta data content and semantics for all data including images. To this end the IMPC has developed automated tools that query the data based on each SOP, including metadata and generate reports that can be viewed in a program called PhenoView. PhenoView enables real-time interaction with the displayed data, allowing users to interactively filter out data points by gender and zygosity and to dynamically configure the statistics displayed. These

are reviewed by a team of specialist with expertise in data analysis and biology, whom we refer to as “Data Wranglers”. Phenoview is a publicly accessible web-based tool (<https://www.mousephenotype.org/phenoview>) developed by the IMPC for visualizing genotype-phenotype relationships. It provides access to the IMPC phenotype data through a grid-like interface. The team of Data Wranglers monitor baseline of each center and compares all centers baseline data over time to check for drift or significant changes in the data. The team then reports back to each center any discrepancies with the metadata, SOPs or the actual data collected. These issues must be resolved prior to data release. QC'd data are then analyzed with a package of statistical analysis tools, termed PhenStat, that has been developed for each specific type of test. Phenotypes are annotated or called, which are again reviewed for voracity by the Data Wranglers. Once QC and PhenStat analysis are complete, the data are released to the web portal of the IMPC.

One of the guiding principles of the IMPC is that all data are freely available via web portal without holdback. Access to data and

software is maximized so that pre-QC data is available via the portal as soon as it passes validation. At data release all data where QC issues are exported to the CDA for analysis and data release. At all times, a versioned data release as well as pre-QC data are available for consortium and community use and previous data releases are made accessible on the FTP site. Complete release notes are available on analysis version and software version. Our code is freely available and licensed with an open source license. Access to data is via web portal (both pre- and post- QC data), API (post-QC data) and FTP site (post-QC data). We integrate data from community resources providing clear links back to the resource (e.g. MGI ids link to MGI). Access to expertise is via our tool, site and training documentation at <https://www.mousephenotype.org>.

We operate a helpdesk, backed by a ticket system, which is staffed by data wranglers who answer queries, or transfer these to data scientists, developers or data generators depending on the query type. Data access is unencumbered now and will continue to be so.

Resource Data Sharing Plan

The consortium has a 5-year track record of sharing data, skills, training, code, tools and has institutional commitments to data and code sharing (subject to existing ethical regulations) and are also committed to open access publishing. EMBL-EBI has provided community access to biomedical data for over 30 years. Our code base, data and toolkit is publicly accessible from an open github repository (<https://github.com/mpi2>). Free and unencumbered access to data is provided via our web tools, APIs, and data downloads, available as per graph data, or a complete dataset. In the future, we will investigate cloud access to the database and data supporting project analysis publications will be clearly linked to a documented version, providing a robust scientific record. Data is provided in bulk to resources such as MGI, OMIM, Monarch and Ensembl (via API or FTP) who display the data in a local context and colleagues at HMGU (Germany) and RIKEN (Japan) have developed add on tools for visualization to provide

a network of data sharing tools for the datasets we manage. We have integrated access to the KOMP repository (USA) and European Mutant Mouse Archive (EMMA) to enable the community to access materials and data in a single resource and provide a service to direct user requests to the appropriate repository or KOMP center where live mice are available. In doing so we also track publications made based on KOMP mice using an automated approach and make this information available to the public period. At the end of the project we will provide the final release of the data, maintain the final version of the website, programmatic access and bulk downloads. As the data are integrated into many other community resources we expect that this will continue and access will be maintained. We will explore integration with NCBI and EBI BioSamples databases and IMSR as a long term archival repository for the data and mouse strains.

Alignment of IMPC Case Study with GSO Framework Criteria

IMPC aligns with the GSO Framework Criteria as follows:

1. Core purpose of global research infrastructures

The goal of the IMPC was and is to provide functional information in the dark area of the genome where genes exist but no or little function is known. A ground up effort was launched by existing national mouse infrastructure in the EU, North America and Asia to combine research facilities to unite in a joint project to complete the entire genome study using gene knockout mice. This reverse genetic approach was to simply delete the gene or disable it to determine the biological consequences of the loss of the gene. The overarching

goal of the effort is to complete an Encyclopedia of mammalian gene function. Such an effort would not be possible in a single or even several existing centers, but requires an international collaboration to leverage resources to accomplish the project goals. All centers are encouraged, challenged and funded to be innovative to develop or incorporate new and emerging technologies. Each center is a focal point locally and nationally to provide services, expertise and training to other researchers. IMPC offers unprecedented capabilities and capacity for reaching the goal of the mutant mouse encyclopaedia and beyond. The IMPC makes all data and materials (mice) freely available to the research community without merit review. One requirement to be a member of the IMPC is that all members adopt the IMPC

protocols for generating mice, standardized types of phenotype data collection (including meta data), SOPs for tests, and data handling. All IMPC data is sent to the Data Coordinating Center (DCC) which performs QC of the data and only upon approval is the data uploaded to the IMPC public website and database. The DCC data wranglers monitor the data and each center to ensure data quality across all tests.

One of the guiding principles of the IMPC is that all data are freely available via web portal without holdback. Access to data and software is maximized so that pre-QC data is available via the portal as soon as it passes validation. Data is provided in bulk to resources such as MGI, OMIM, Monarch and Ensembl (via API or FTP) who display the data in a local context and colleagues at HMGU (Germany) and RIKEN (Japan) have developed add on tools for visualization to provide a network of data sharing tools for the datasets we manage. The IMPC have integrated access to the KOMP repository (USA) and European Mutant Mouse Archive (EMMA) to enable the community to access materials and data in a single resource and provide a service to direct user requests to the appropriate repository or KOMP center where live mice are available. In doing so the DCC also track publications made based on KOMP mice using an automated approach and make this information available to the public.

In conclusion, while the IMPC started in the same time frame and developed in parallel to the GSO efforts, there is remarkable similarity to the proposed framework of the GSO and the path the IMPC followed. Had the guidelines been available at the time of the IMPC launch, they would have clearly helped form the foundation for much of the process of the IMPC. While both the IMPC and GSO developed mostly independently, it is clear that the IMPC follows these guidelines and the perspective of the IMPC is that the GSO guidelines have largely hit the mark and form an excellent blueprint for how to develop future projects and infrastructures.

2. Defining project partnerships for effective management

The IMPC concept, organization and governance was developed through a core of interested research centers and funders based in the UK, the MRC, the MRC-Harwell, the Wellcome Trust and the Wellcome Trust Sanger Center, and soon joined by the NIH (USA) in 2008 to 2009. A business plan was developed that described the need, scope, opportunity, risks and structure for a global IMPC project. The pre-planning was critical to the development of the project, as was the description of the scientific approach. The Governance Documentation of the IMPC, while not legally binding, defined the roles and responsibilities of the partners and described the criteria for new partners to join. Using the IMPC Business Plan, several organizations joined the IMPC and several used this as a launching point to obtain funding to join the effort. Some groups were also able to build or expand local research infrastructures to engage in the IMPC project, notably in Monterotondo, Italy and Prague, Czech Republic. The defining of partnerships was a critical step in the IMPC Project and the GSO framework in this area meshes perfectly with what transpired in the IMPC, and should be a model in the future, both for newly built research facilities and global project initiatives that use existing infrastructures such as the IMPC. A track

record of experience in high throughput phenotyping and/or large-scale knockout mouse production, allied to the physical resources to undertake such activities, or expertise in specialized ("Secondary level") phenotyping that would add value to the resource and database. For phenotyping centers, a commitment to phenotype not less than 50 lines per year. For production centers, a commitment to generate not less than 50 lines per year, with the ability to distribute live mice, embryos, and sperm. For Secondary level phenotyping groups, a commitment to share data with the IMPC as a whole, and deposit the data into the IMPC Database in a timely fashion. Agreement to work within the framework of the consortium, including commonly agreed phenotyping pipelines and IT structures. Agreement to the full release of data to data coordination centers according to IMPC agreed procedures and timelines. Agreement of production centers to provide the community access to live mice, embryos and sperm as soon as possible without intended hold backs, subject to legal or MTA restrictions. Upon application to the IMPC, an applicant must receive unanimous approval to join the IMPC. Furthermore, as members must obtain their own funding for the project there are other layers of review from funding bodies.

3. Defining scope, schedule, and cost

Each IMPC member is responsible for designing the scope and timing of the project for inclusion in the IMPC. The Members must secure funding from local or international funding bodies to finance the project. The IMPC then reviews the proposed project to determine if the project is appropriate for inclusion into the IMPC. Once a member of the IMPC, the Steering Committee via the Data Coordinating Center tracks the progress of the project. Should any member fall behind of their goals, they can be put on notice for non-compliance. This has not occurred to date. The Centers are responsible for tracking budgets and reporting back to their funding bodies. The IMPC does not provide fiduciary oversight.

4. Project management

IMPC is governed by the IMPC Consortium agreement, managed by the Executive Director and Chair of the Steering Committee. Each member appoints a representative to sit on the Steering Committee. The Steering Committee reports formally to the Panel of Scientific Consultants ("PSC") once a year, providing a comprehensive report on achievements set against deliverables and milestones of the program. The Steering Committee is chaired by a Scientist, elected by a majority vote of the Steering Committee. All permanent members of the Steering Committee vote on new members; according to criteria for membership. The Steering Committee establishes agreed milestones and deliverables for the project with input and advice from the PSC and the Executive Director. Meetings are held regularly and additional meetings may be called by the Secretariat and the Steering Committee Chair, or at the request of the member representatives. Meeting dates/times are decided by polling and take place at times convenient to the most of the member representatives. It is highly desirable that motions, issues and recommendations are decided by consensus of the group present at meetings. Motions to approve require 75% majority of the members voting. It is recognized that some decisions may not be applicable or enforceable to all groups, due to different operations of the various groups, financial restrictions, and

legal issues of the funding organizations and/or research groups. In such instances, where compliance or acceptance of an IMPC policy or decision is not possible, it must be brought to the immediate attention of the IMPC Steering Committee and those members should abstain from voting on issues to which they could not comply. In the event that a 75% majority of the Steering Committee deems that a research group is not meeting their deliverables for the IMPC in the manner in keeping with the high expectations of the IMPC for collaborative efforts, throughput of lines, and data quality, the Steering Committee may put the group on notice that their membership in the IMPC is in jeopardy.

The Steering Committee has appointed an Executive Director who reports to the Steering Committee through the Chair of the Steering Committee. The Executive Director is responsible for coordinating the activities of the IMPC necessary for delivery of the IMPC production pipeline and related products such as mice and biological materials, datasets and functionality of the IMPC Database. The Executive Director ensures that members are in compliance with the IMPC goals, quality requirements, and community needs. The Executive Director helps facilitate cooperation between research groups and works with these groups and the Panel of Scientific Consultants (PSC) to continually monitor the quality and value of the IMPC datasets, and to explore new technologies and methodologies to improve the product. The Executive Director also serves to mediate any disputes between member groups of the IMPC. The Executive Director serves as spokesperson for the IMPC and assists members and potential members in their fundraising efforts by providing data, reports, and making presentations where necessary.

5. Funding management

This point is less applicable to the IMPC as there is not a common pool of funds to finance the project but instead contributions to the project come from individual countries to fund the individual centers. Each member is responsible for obtaining funding for their part of the project. The IMPC accepts members that can contribute on many levels, from the actual production and analysis of mutant mice, informatics and downstream analysis on a more in-depth level. Each application is reviewed for membership without preset limits. The IMPC then commits to work to facilitate smooth and harmonious integration of the research networks individual projects and to work to help communicate the goals and milestones of the IMPC to the wider scientific community. An IMPC secretariat helps manage this process and is funded by in-kind contributions and a membership fee. The membership fee is currently a one-time payment of \$100,000 CANADIAN. The fee may be paid, in full or in part, with in-kind contributions, or adjusted in the future subject to approval of 75% of the Steering Committee.

6. Periodic reviews

The IMPC programs are reviewed by their individual funding bodies and by the IMPC Panel of Scientific Consultants on an annual basis. The IMPC set up a Panel of Scientific Consultants (PSC) at the outset of the project. The PSC conducts quarterly teleconferences to review progress on project goals, discuss any issues, review special topics and provide community feedback to the IMPC. The PSC also attends

the IMPC Annual Meeting and provides a written report on the quality of the science, progress evaluation, community impact, relevance and value to the community and funders. This report is presented to PSC and provided to funding organizations.

7. Termination of decommissioning

As each center is self-funded and utilizes pre-existing multi-use animal facility, no decommissioning is planned. The IMPC does have ongoing products-mice and data. The mice or germ plasma are provided to Mouse Repositories for storage and to provide access to investigators. The Data is housed by EBI and long-term maintenance is needed upon the completion of the project.

8. Access based on merit review

The IMPC makes all data and materials (mice) freely available to the research community without merit review. To become a member of the IMPC and contribute to IMPC data, however, requires a strict review performed initially by the IMPC Director who helps applicants develop application materials to meet the IMPC requirements. This is followed by a formal application to the IMPC Steering Committee.

9. E-infrastructure

The IMPC Data Policy. All IMPC data are submitted to an IMPC Data Coordinating Center that provides data quality control and coordinates with centers to standardize data and maintain quality. After QC, data are released via a web portal and freely available to all users. Information and instructions are provided to allow users to freely download all data sets. All datasets are Cloud based and online data visualization tools are provided. <https://www.mousephenotype.org/data/tool>

10. Data exchange

One of the guiding principles of the IMPC is that all data are freely available via web portal without holdback. Access to data and software is maximized so that pre-QC data is available via the portal as soon as it passes validation. At data release all QC data are exported to the CDA for analysis and data release. At all times, a versioned data release as well as pre-QC data are available for consortium and community use and previous data releases are made accessible on the FTP site. Complete release notes are available on analysis version and software version. Our code is freely available and licensed with an open source license. Access to data is via web portal (both pre- and post- QC data), API (post-QC data) and FTP site (post-QC data). We integrate data from community resources providing clear links back to the resource (e.g. MGI ids link to MGI). Access to expertise is via our tool, site and training documentation at <https://www.mousephenotype.org>

We operate a helpdesk, backed by a ticket system, which is staffed by data wranglers who answer queries, or transfer these to data scientists, developers or data generators depending on the query type. Data access is unencumbered now and will continue to be so.

11. Clustering of research infrastructures

The IMPC embraces the philosophy of clustering or amalgamating complementary research infrastructure. Pre-existing consortia such

as mouse repositories for distribution of materials EMMA (Europe) and MMRC (USA), MGI (mouse genome informatics), InfraFrontiers (EU infrastructures) and the IKMC (International Knockout Mouse Consortium) have all either joined, melded or integrated data and access sharing with the IMPC.

12. International mobility

International mobility is not specifically relevant to the IMPC as there is not a centrally funded facility that hires people with IMPC funds. The IMPC have however fostered the exchange of ideas and workshops on an international level. Several IMPC members have spent significant time at other sites for training.

13. Technology transfer and intellectual property

The IMPC members have agreed that all data and mice be made freely available and free of intellectual property encumbrances. In order to make this a smooth and coordinated process, the IMPC formed a Material Transfer/IP sub-committee. The purpose of the sub-committee was to review any potential IP issues and review and harmonize Material Transfer Agreements. While some institutions and jurisdictions have special requirements, all efforts were made to ensure that the MTA reflects the same requirements across the IMPC. Any technology developed by an IMPC member remains the property of the IMPC center that developed it, but such developments cannot be used to interfere with the basic principles of data and mouse availability.

14. Monitoring socio-economic impact

The socio-economic impact of the IMPC was a central tenant of the project's conception. A systematic production and coordinated analysis of gene knockout mice on a genome level saves investigators

a vast amount of repetitive non-productive duplicative work, as the work is being performed in a central and publicly accessible manner. Socially, it also reduces the numbers of animals used in research and prevents waste as multiple labs will not unknowingly repeat similar studies, which addresses serious social animal welfare concerns. Furthermore, from the beginning the IMPC studied both male and female cohorts of mice in the core phenotyping pipeline and the IMPC data of the prevalence of sexual dimorphism has helped funding agencies solidify their views and the requirement that experimentation must address male and female subjects. Members of the IMPC consortium have extensive experience in coordinating diverse activities between multiple production and phenotyping centers to create a network that produces high-quality mouse strains and data for the biomedical research community. We have successfully delivered excellent outreach and training via conferences and meetings, training courses, distribution of promotional materials such as flyers, posters and newsletters, and our web portal and social media presence. Previously we have produced an online training course to show users how to make effective use of the IMPC portal <http://www.ebi.ac.uk/training/online/course/impc-using-mouse-phenotyping-portal>. This was hosted on the EBI's training portal and developed in collaboration with professional trainers from the EBI's training team. We will provide new content as core components are deployed and data become available. All face-to-face training will be accompanied by a survey, and training pages of the IMPC portal will be supported by a 'contact us' function, allowing people to register interest in future training events. Collaboration and our leadership within these projects have allowed us to perform international engagement with Japan, Australia, South Korea, Taiwan, European Union countries and others.

EUROPEAN SPALLATION SOURCE

Progress Report on ESS Case Study

Prepared for the Group of Senior Officials on Global Research Infrastructures

Executive Summary

In 2015, the GSO selected the **European Spallation Source ERIC-ESS** as one of five case studies in a pilot exercise aiming to investigate and promote various options for international collaboration. While large-scale research facilities play an increasingly important role in solving contemporary societal challenges, a single country alone often does not have the funding and expertise necessary to build and operate them. The mandate of the GSO is, among other things, to promote international collaboration and analyse how countries evaluate and prioritize the construction of large-scale research facilities. The approach taken at ESS – to build and operate the world leading neutron source mainly through in-kind contributions (IKC) from international partners – can serve as a source of inspiration for other single-sited research facilities under construction seeking to increase their membership base and strengthen their network of partners.

As a partnership of 15 countries, the European Spallation Source is special in its approach to construction through in-kind contributions from institutes in the Member States. The IKC process adopted by the organisation serves to deploy the expertise of scientists and engineers from all over Europe and mobilise their knowledge to deliver an unprecedented facility for the use of the international community. IKC are non-cash contributions in labour or material to ESS and have several important purposes. They allow Partner Countries to politically justify their investments in an international project outside their borders by ensuring that some of the value of their contributions remains with their respective institutions and industry. They enable technology transfer through the participation of the organisations in the construction of a large-scale Research Infrastructure. Lastly, they allow ESS to leverage the collective knowledge, experience and resources of Europe's leading research institutions and industry.

Partnership building is essential to a successful and timely construction of the ESS facility, which is one of the largest science infrastructure projects being built in Europe today. The organisation has established an internationalisation model that allows interested countries to take a series of small steps on their way to full membership. Fifteen countries have joined the European Spallation Source ERIC and the organization actively seeks to enlarge its membership base. The European Spallation Source and potential new Member Countries must satisfy a set of overlapping criteria related to scientific knowledge, funding, and political motivation. The European Spallation Source ERIC Statutes currently allow two forms of collaboration between ESS and national states and their respective research institutes and industry:

- **Member:** Members are represented in the European Spallation Source ERIC Council and jointly decide on the ESS scientific programme, the overall allocation of beam-time and the budget in the construction and future operations phase.
- **Observer:** Observers are national states who have indicated in writing to the Council that ESS fits with their own national scientific agenda on material sciences, and who wish to participate fully in the Research Infrastructure. Normally Observers shall be admitted for a three-year period. Observer status means that the national state can be present at Council meetings, but it does not have a vote.

In order to anchor ESS as a truly international facility, the organisation is currently working on identifying new categories of membership, which would provide for additional forms of collaboration between ESS and national states outside the European Research Area. The involvement of ESS in the GSO has further encouraged the organisation to move in this direction and pursue a global membership base. The broad international character of the GSO has supported ESS in the process of establishing contacts with stakeholders outside Europe. The framework has complemented the stand-alone efforts of ESS and has proved to be helpful in opening avenues for strategic dialogues with GSO countries such as Brazil, Canada, China, India, Japan, and Russia.

The European Spallation Source aligns with the GSO Framework Criteria introduced with the aim to secure a coherent and coordinated world-wide development and operation of Global Research Infrastructures. The fourteen criteria address a number of important technical, managerial, economic, and organisational aspects related to the building and operating of large-scale research facilities. The criteria are exhaustive and provide a good framework for a unified approach on the global scale.

Introduction

The European Spallation Source is a research infrastructure committed to the goal of building and operating the world leading facility for research using neutrons. The ESS will deliver a neutron peak brightness of at least 30 times greater than the current state-of-the-art. Generating neutron beams for science will add value to a broad range of research, from life science to engineering materials, from heritage conservation to magnetism. Smaller and more complex samples will be accessible for neutron investigations, making the study of rare and biological samples and samples under extreme conditions possible, among other things. These gains will bring a paradigm shift in neutron science, and expand the use of neutron methods, providing the wider research community with a smart new set of experimental options.

The ESS officially became a European Research Infrastructure Consortium (ERIC) in October 2015. The Founding Members of the European Spallation Source ERIC are the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Sweden, Switzerland, and United Kingdom. Founding Observers, who intend to become Members in the near future, are Belgium, the Netherlands, and Spain. This collaborative multinational project is also one of the largest science infrastructure projects being built in Europe today.

The facility is under construction in Lund (Sweden), while the ESS Data Management and Software Centre (DMSC) is located in Copenhagen (Denmark). A total of 15 instruments will be built during the construction phase to serve the neutron user community with more instruments built during operations. The suite of ESS instruments will gain 10-100 times over current performance enabling neutron methods to study real-world samples under real-world conditions.

Foreseen milestones include: the facility is ready for the accelerator beam on target (Spring 2020), the first call for user proposals (2022),

the Machine is installed for 2.0 GeV performance (December 2022), the start of the user programme (2023), and the completion of the construction phase of instruments (December 2025).

A single country alone often does not have the funding and expertise necessary to build and operate a project of such a complex nature. To achieve a “global research infrastructure” a concerted international effort is required combining the best available knowledge, human capital, funding and resource. As one of the largest facilities on the ESFRI roadmap, ESS is an essential building block towards a future-oriented and competitive European Research Area and Global Research Infrastructures. The European Spallation Source is special in its approach to construction through in-kind contributions (IKC) from participating institutes in the member states. Collaboration on a European and global level provides access to frontier technology, as well experienced technical and scientific personnel and access to unique production facilities and technologies. IKC also translate into important socio-economic driver fuelling national innovation potential, competitiveness, and the national GDP of all of the member states for the long term. This will increase each country’s national and cross-national capacity and help create jobs and growth.

The European Spallation Source has been selected as a pilot case study to better understand the process behind a possible effort to move from a national/regional perspective to a global effort. The ESS is an example of a European Strategy Forum for Research Infrastructures (ESFRI) project to provide insight to European best practices in terms of launching a multinational collaborative effort. The ESS model for expanding global scientific and technical partnerships can serve as a source of inspiration for other international single-sited research facilities.

Best-Practice: In-Kind Contributions

Building a state-of-the-art facility is challenging in many respects, even more so when being built from the ground up, on a Greenfield site. In order to successfully construct ESS in the required time frame, experts, scientists and engineers from all over Europe are mobilising their knowledge and experience. International collaboration and in-kind contributions allow ESS and its Partners to complete more work in parallel. The coordination of such an effort can be challenging, but the rewards are tremendous as well. This collaboration of more than 40 institutions, working together with one goal, enables the power of European science to deliver an unprecedented facility in a relatively short time frame.

BACKGROUND AND PURPOSE OF IN-KIND CONTRIBUTIONS

The ESS greenfield development and IKC approach was chosen because the costs of building and operating the world’s most powerful neutron research infrastructure is neither economically feasible nor politically achievable at a national level. Other ERICs manage large consortia of partners and stakeholders as well, but they do not nearly have the centralised hardware technology requirements of ESS at a time of difficult economic conditions. The only way to allow ESS to move from initiation to construction has been to carry out the majority of work at national level, using national funding and working on the premise that the benefits should lie primarily at national level before the ESS starts its operations.

The In-Kind Contributions to ESS have several important purposes. They allow Partner Countries to politically justify their investments in an international project outside their borders by ensuring that some of the value of their contributions remains with their respective institutions and industry. They enable technology transfer through the participation of those organisations in the construction of a large-scale European research infrastructure. They allow ESS to leverage the collective knowledge, experience and resources of Europe's leading research institutions and industry.

Work and activities relative to establishing In-kind Contributions have been ongoing since 2013 when ESS published the Call for Expression of Interest and invited all interested parties to annotate their interest in in-kind contributions to the construction. These contributions are expected to finance more than 645 million euro, or 35% of the total 1,843 billion euro (2013) construction costs. Overall, ESS has identified a project scope with a potential value of 664 million euro, equal to 61% of the ESS technical work scope. The total current value of IKC work packages with Partners is €312 million, nearly half the estimated potential value. That value will continue to rise.

The Partner facilities and ESS project teams continue to identify work that may be done by IKC Partners. There are important decisions still pending on the distribution of IKC relative to Neutron Scattering Systems, Instruments and Integrated Control Systems. This is expected to raise the total planned IKC close to the goal of 35% of the project value. Already now, ESS has a track record of successful awareness raising activities and campaigns, which have helped the organization to engage stakeholders in various countries and increase the overall IKC. Within the framework of the EU- funded project BrightnESS, ESS has established regional hubs in its Partner Countries to maximise the common knowledge on how to best execute IKC. The organisation has also set-up an online IKC Best Practice Platform which allows Partners and other stakeholders to find and exchange information, and benefit from sharing key documents that facilitate both the preparation and the implementation of an in-kind model in European Big Science Projects.

DEFINITION OF ESS IN-KIND CONTRIBUTIONS

In-kind contributions are non-cash contributions in labour or material to ESS. An IKC may cover technical components as well as personnel needed to perform testing, installation, and integration. In-kind Contributions may also include R&D work needed during the Construction Phase. Other products or services relevant for the completion of the ESS facility may be included as well, as long as it is a planned part of the construction project and agreed between ESS, the Partner institution and the Member Country. In addition to the advantage for the ESS project, there are also important benefits that the Member Countries will realise as a result of their contributions. It allows Partner institutions to have focused networking possibilities with international Partners, and at the same increase local know-how. Working on a large-scale research infrastructure creates unique employment opportunities in the Member Countries, contributes to national economic growth and fosters the growth region of regional

economies in high-value technological and specialised industries. It also allows the Partner institutions direct access to ESS research into cutting-edge technologies.

Potential in-kind contributions are defined by the ESS Programme Plan and their values are based on the ESS Cost Book. The ESS Construction Cost Book provides the total cost for the construction of the ESS facility and presents the cost-related details of each Work Package and Work Unit. Agreed in March 2013, the Cost Book covers construction phase only and is based on January 2013 cost levels. For each project and area, the cost is broken down into detailed packages with a short description, cost value and indication of in-kind potential. The cost does not include VAT or cost for hedging and the prices are listed in euro. Cost contingency has been included in the cost of the construction of ESS to cover uncertainty pertaining to the precise content of all items in the estimates, market conditions, technical challenges, unforeseen events etc. According to the January 2013 pricing, the total construction budget and ESS Cost Book Value is 1,843B euro. The Cost Book also set the target for annual operations cost at 140M euro. Together with the Call for Expression of Interest, the Cost Book assists potential contributors in determining how to join the ESS project. The table below indicates the percentage of costs committed by each Member and Observer Country and also the form of contribution to ESS.

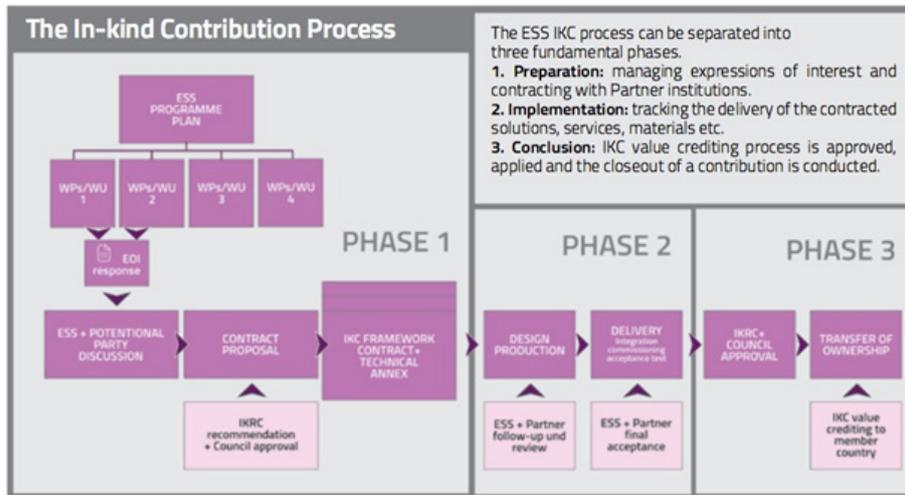
Country	Percentage of Total Funding	Form of Contribution
Sweden (member)	35 %	Cash
Denmark (member)*	12.5 %	Cash
Germany (member)*	11 %	IKC
United Kingdom (member)	10 %	IKC
France (member)	8 %	IKC
Italy (member)	6 %	IKC
Spain (observer)*	5 %	IKC
Switzerland (member)	3.5 %	IKC
Norway (member)	2.5 %	IKC
Poland (member)	2 %	IKC
Czech Republic (member)	2 %	IKC
Hungary (member)	0.95 %	IKC
Estonia (member)	0.25 %	IKC
Belgium (observer)	TBD	TBD
Netherlands (observer)	TBD	TBD
TOTAL FUNDING*	98.7 %	

*Includes Pre-Construction Costs, Current Construction Commitment

IN-KIND CONTRIBUTION PROCESS

In order to make the collaborative effort work, a framework has been created and Partners have systematically matched their skills and

expertise with the needs of the project. The chart below explains the flow and phases of the in-kind contribution process at ESS.



The process of identifying an IKC Partner begins with the ESS project teams. They are responsible for defining the work in their respective projects that can potentially be done as an In-kind Contribution. The value for contributions must be based on the overall ESS budget and project budgets as defined in the cost book. After the work has been defined and a value determined, ESS solicits proposals from potential Partners in the Member Countries. Potential Partner institutions evaluate those In-kind packages and when they see a potential package that is of interest, they can respond with an Expressions of Interest. This begins a discussion between the potential Partner and ESS to reach an agreement on the scope, schedule and cost.

Each Agreement follows a pre-defined structure. The delivering party, in agreement with ESS, is wholly responsible for the contribution

including the technical, financial, and commercial aspects. The In-kind Review Committee (IKRC) evaluates all In-kind Agreement proposals that are reached and signed, and decides to endorse them or not. Finally, the ESS Council approves all the IKRC-endorsed In-kind Agreements. Once Agreements are in place, funding can be released to the Partner and work can begin. Once work does begin, the Partner and ESS project teams continuously monitor progress of the package and other related packages, going through several key milestones. When work is completed, the ESS staff creates a final report for the contribution. Based on the final evaluation, the Member Country receives credit for the value of the In-kind Contribution according to the ESS Cost Book.

International Collaboration and Partnership Building

The European Spallation Source is a partnership of nations committed to design, build and operate the world's leading research facility using neutrons for science and innovation. It is being built on the core values of excellence, collaboration, openness and sustainability. International collaboration and partnership building are of crucial importance for the success of the ESS project.

ESS GOVERNANCE

The European Spallation Source ERIC Council is the governing body of the European Spallation Source ERIC. The Council is made of

representatives from the Member Countries. It appoints the Director General and Chairperson, and approves the budget and technical scope of the facility. The Council is bound by the Statutes ratified by the ERIC Member Countries. The constituting European Spallation Source ERIC Council Meeting was held July 2-3, 2015, where the leadership was appointed, the Council Rules of Procedure were adopted, and the Terms of Reference for all advisory committees were approved by the Council. The European Commission's establishment of ESS as an ERIC occurred on 31 August 2015 and the transition of ESS from a Swedish limited partnership to an ERIC was completed as of 1 October 2015. The ESS project is supported by ESS Governance Committees, which include the ERIC Council, Administration and

Finance Committee (AFC), and In-kind Review Committee (IKRC), and a number of independent ESS Advisory Committees, which include Scientific Advisory Committee (SAC), Technical Advisory Committee (TAC), Conventional Facilities Advisory Committee (CFAC), Environment, Safety & Health Committee (ES&HC), and Committee on Employment Conditions (ECC). Recommendations by each committee advance ESS along the critical path to completion. The committees consist of delegates representing the Member Countries or experts which evaluate and advise the progress of the ESS.

PROCEDURE FOR EXPANDING INTERNATIONAL COLLABORATION AND PARTNERSHIPS

There is a significant interest among new countries to join the European Spallation Source ERIC. The ESS Organisation, together with the Host Countries, is raising awareness and organising networking activities to create opportunities for new partner involvement, funding and collaboration. As of today, 12 countries have joined as Founding Members and 3 countries as Observers of the European Spallation Source ERIC and eventually as members.

In order to anchor ESS as a truly international research facility, which is built and operated by the broadest possible scientific community, ESS intends on expanding the current membership base. During the 4th ESS Council Meeting in February 2016, the Council has defined a set of priorities for the related activities:

- Maximize the contributions to construction.
- Maximize the contributions to operations for new partners.
- Seek partners outside of Europe.
- Increase the membership not only for material support, but also for political support.
- 'Quality' that new members bring is an important additional criterion – potential to contribute scientifically.

The European Spallation Source ERIC Statutes currently allow two forms of collaboration between ESS and national states and their respective research institutes and industrial research facilities.

Founding Member

Founding Members are national states who signed up to the construction of ESS right at the start of the endeavour in 2010. In September 2015, the European Spallation Source changed its legal status as European Research Infrastructure Consortium (ERIC) and established a new governance structure for the Organization and its Partners. ERIC Founding Members are represented in the ESS Council and jointly decide on the ESS scientific programme, the overall allocation of beam-time and the budget in the construction and – future – operations phase.

Observer

Observers are national states who have indicated in writing to the ESS Council that ESS fits with their own national scientific agenda on material sciences, and who wish to participate fully in the research infrastructure. Observer status means that the national state can be present at ESS Council meetings, but it does not have a vote.

Based on an ESS Council decision, the national member state and ESS work out a plan how to move the membership from Observer status to Membership. The transition period to full membership has been set to three years, after which the new member is awarded the same rights and obligations as the original Founding Members.

Below is a summary of the articles in the European Spallation Source ERIC Statutes relating to new Members:

- As already stated, article 17 of the European Spallation Source ERIC Statutes states that the facility should provide access for European as well as international (meaning: non-European) researchers and other users. It also says that the facility will be open for access to other than members.
- Article 3 of the European Spallation Source ERIC Statutes outlines the conditions for Membership of the European Spallation Source ERIC. Members can include the EU Member States, associated countries to the EU, so-called Third Countries (these are states outside the EU with which the EU has a special agreement or (historical) relationship) and intergovernmental organisations. It is important to note that EU Member States or Associated States must jointly hold the majority of voting rights in the ESS' highest decision making body, the Council.
- According to Article 4 the Council can admit new Members after a written request to join and after an approval vote. The written application must include a description of the contribution the new Member intends to make to ESS, in addition to how the new Member will adhere to the Statutes in respect to contributions and appointment of representing entities. New Members who can adhere to the Statutes within a period of 12 months can do this under the same conditions as the Founding Members. This is done through a bilateral agreement between ESS and the new Member. Furthermore, the new Member is required to make a financial contribution towards the capital expenditure of ESS already incurred, in addition to their regular contribution. Entities who are not (yet) able to join as a full member, can still participate as Observer to the Council. Observer status is granted for a period of three years, unless the Council decides to extend this period.

Chapter 3 and Chapter 4 of the Statutes govern the rights and obligations of Members. Membership gives the right to vote in the Council. The Council decides – among other things – on budget, the medium-term scientific programme and the policy for the allocation of and access to beam time. Observers do not have voting rights in the Council. The number of votes in the Council corresponds to the Member's contribution to the cost of pre-construction and construction. Once the operation phase starts this apportionment of the Council will revisit votes. Contributions to ESS can be provided

in cash or in-kind to the pre-construction and the construction phase. The members will also contribute to the operating costs of ESS proportionally to their use of the research facility. Contributions per Member are apportioned in the annual budget as decided by the Council.

INTERNATIONALISATION MODEL

As clearly stated in the European Spallation Source ERIC Statutes, ESS is not limited to purely European membership, and aspires to become a Global Research Infrastructure. In practice this means that the current Membership structure will need to be modified to allow global membership of ESS on an equal footing to the membership of the existing Founding Members. The organisation is currently working on identifying new categories of membership, which would provide for additional forms of collaboration between ESS and national states than currently allowed by the Statutes. The involvement of ESS in the GSO has further encouraged the organisation to move in this direction and pursue a global membership base. A global membership structure helps developing countries, with currently limited resources to fund their own infrastructures, to build or improve their scientific and industrial competitive capacity. For countries that have facilities for neutron research, ESS will become an added capability for companies and academics that need access to beam-time for their research.

Being a Member provides added value in addition to 'excellence based access' in that Members jointly decide in the governing Council on – among other things – budget, the medium-term scientific programme, and the policy for the allocation of and access to beam time, and innovation activities. Scientists from non-Member States will be able to compete for the remaining beam-time based on a competitive peer-assessment, but not access to the decision-making bodies of ESS.

To increase the current membership base, ESS and potential new Member Countries must satisfy a set of criteria that overlap as much as possible. These criteria, and more, must be evaluated and weighed, when making a decision to join ESS.

Criteria for ESS	Criteria for potential new Member Countries
Close the funding gap for construction	Strengthen scientific communities for material sciences, support existing communities, or even build new capacity and communities
Strengthen and broaden the scientific/expert knowledge for construction and science	A desire to participate in international research infrastructures
Increase the base for contributions to operations	Some concern about the ability to finance such a project depending on the macroeconomic situation
Provide a broader base of political support at both European and global levels	Political motivation/ commitments

ENGAGEMENT POLICY

The following sections describes the detailed sequence of activities ESS is already implementing and will continue to formalise, and places them in a logical framework. With this process we are enabling new potential Partners to join by giving them a clear incremental path to become Members. In-kind Contributions and science are an integral part of the entire process.

Making a series of small steps reduces the level of commitment necessary in any single decision, and allows for consensus building. Having a clear and established process enables potential Partners to understand, communicate and structure their own decisions. It also allows a time frame to be established and helps prevent overlooking important preconditions that enable a successful accession.

Phase 1: Establishment of Contact

When an appropriate representative of ESS has identified a new potential ESS Member Country, there are several paths forward. Depending on the relevant target group within the potential Member Country and the corresponding knowledge within ESS, contact may be established directly on high political level or if there are established contacts between a representative of ESS and the scientific community in the potential Member Country, it may be more viable to pursue a bottom up approach. Once the contact is established, contact details and correspondences are shared and archived in the ESS Contact management system or on the shared server.

Phase 2: Collection of Information

When a country is identified as a potential candidate to become a new ESS Member Country, External Relation collects information on

the candidate's relevant background, such as scientific community, institutes, industry, funding scheme, political structure, related network etc. Additionally, ESS employees from the respective country are interviewed and information recorded. The collected information is compiled in a Country Report and a target group analysis made, as well as a contact database established. Neighbouring or related ESS Council Members (ex. ES for PT; UK for IE) are approached for relevant input on the drafted Country Report. Finally, the established Regional Hubs are employed to compliment and complete the established country report.

Phase 3: Awareness Raising

An enlargement plan specifying the awareness raising measures for each country is set up by by ESS Management and Communications and External Relations. Initially, bilateral meetings with potential stakeholders and appointed representatives from ESS are organised establishing the necessary channels to national stakeholders.

When a certain threshold of interest is established, a tailor made activity (ex. Partner Day, Scientific visit, Workshop etc.) is organised in the potential Partner Country to explore contribution and collaboration possibilities. The event is hosted by one or more stakeholders and implemented by the External Relations Team with support from partners as well as competences from in-house staff of the respective country. After each activity a status report is submitted to the ESS EMT and the activities followed up to maintain the established contact.

Phase 4: Accession

Once a potential Member Country has expressed interest in joining the European Spallation Source ERIC, a Country Coordinator will be appointed from Communications, External Relations and In-kind Division. External Relations will support the new Partner Country with information and facilitate contact in preparations of the accession process as is defined in the ERIC Statutes. The new Member Country is invited to participate in the ESS Governing bodies (ERIC Council, AFC, IKRC) and ILO Network. The Country Coordinator together with the ESS Projects and In-kind Coordinator work with the contact or target group in the potential Member Country to identify the possible In-kind and collaboration opportunities to anchor the membership. All necessary documents will be compiled and maintained to keep information up to date.

A country may join the European Spallation Source ERIC as 'Observers', which is a transitional status and intended to allow potential new members to join the ESS Council Meetings and have access to the European Spallation Source ERIC for the purpose of increasing understanding about the organisation. This increased understanding is meant to enable potential new members to have the necessary information to decide when and how to join the European Spallation Source ERIC as a full member. It does not require a financial or political commitment.

Phase 5: Establishing In-Kind Agreements

In-kind Agreements are defined to move to the final level of making the commitment concrete. Observers can negotiate for in-kind, but should do so on the basis of a real financial commitment, otherwise ESS will spend time negotiating with Partners that won't commit in time, risking delays for ESS and possibly competing with existing Members; also moves the process forward rather than stagnating as sometimes happens politically.

Phase 6: Join the European Spallation Source

Once the amount and timing of commitments is finalized and approved by the Council, in-kind Partners can work and the country can become a fully-fledged member of ESS.

The process of Enlargement will develop and evolve over time. International countries or entities will surely require an adapted approach to becoming an ESS Member/Observer as there will be new and different challenges to overcome, such as for example political and legal contexts on an international level, among other issues. Additionally, once the facility is completed and enters the Operations phase, amendments to the Statutes may be necessary in regards to enlarging the Member base as partnerships and collaborations during the Operations phase will be of a different nature than during the Construction phase.

The Communications, External Relations and IKC Division manage enlargement efforts at ESS. The Head of External Relations leads a specific initiative known as the 'Enlargement of the ESS Member Base'. All activities related to enlargement and attracting new Members, will be managed in this context.

STATUS OF ENLARGEMENT NEGOTIATIONS

The European Spallation Source ERIC currently has 12 Founding Members and 3 Founding Observers throughout Europe. The ESS is raising awareness and organising networking activities to create opportunities for new partner involvement, funding and collaboration. The approach taken at ESS – to build and operate the facility as an international collaboration by many states – fits very well with today's view that scientific breakthroughs are most likely to occur from synergy between research domains and between people who approach a research challenge from different educational, scientific and cultural backgrounds.

A near-term priority for enlargement activities is to turn Observers into Members. A successful transition into Members will provide a foundation for the process and demonstrate the necessary steps to be taken for turning Observers or Potential Members into full Members. A medium-term priority is to prompt countries that have signed from 2009 onwards a Memorandum of Understanding (MoU) with ESS into becoming Observers and later Members. Finally, a long-term aim is to engage other European countries and international countries to join the European Spallation Source ERIC as Members.

The European Spallation Source is in close contact with countries in the European Research Area such as Greece, Latvia, Lithuania, Portugal, and Turkey, all of which are interested in closer collaboration with ESS. In the framework of the GSO, ESS is exploring interactions with several international players to expand the scope and opportunities that will drive for excellence. Below is a summary of main collaborative achievements in those GSO countries where the engagement of ESS with local stakeholders is most advanced. The European Spallation Source has successfully established solid bilateral contacts with the scientific communities of Brazil, Canada, China, India, Japan and Russia.

Brazil

The ESS Director for Science, Andreas Schreyer, discussed new possibilities for scientific cooperation between ESS and Brazil during the “Brazil-Sweden Excellence Seminar” organized in Brasilia on 16-20 May 2016. The important role of the seminar was underlined by the participation of a high-level delegation from one of the ESS host countries – Sweden, which comprised of the Swedish Minister of Higher Education and Research, Helene Hellmark Knutsson, representatives of funding agencies and leading figures from the Swedish academic and scientific communities. The seminar unveiled the strong interest of Brazilian scientists in establishing close ties with neutron research centres in Europe. In this regard, the ESS project presents an unparalleled opportunity for Brazil to work directly in the collaboration with international partners to construct and operate the world’s most powerful neutron source. In addition, ESS hosted José Roque da Silva, Director of the Brazilian Synchrotron Light Laboratory (LNLS), on its premises in Lund on 20 June 2016 and further discussed capacity building, including exchange of scientists, between Brazil and ESS.

Canada

Upon the suggestion of Dr. David Moorman, Senior Program Planning Officer of the Canada Foundation for Innovation (CFI), ESS contacted Prof. Christopher Wiebe, President of the Board of Directors of the Canadian Institute for Neutron Scattering, and proposed to explore concrete collaboration opportunities. As Canada plans to shut down its primary neutron source, the National Research Universal (NRU) reactor, ESS also extended the offer to provide a stimulating and credible home for the dynamic community of neutron users in Canada. The ESS Management briefed the Canadian neutron users about ESS and discussed concrete collaboration opportunities during the 2016 Annual General Meeting of the Canadian neutron beam community hosted by McMaster University on 14-15 October 2016. Alongside the Annual Meeting, ESS also held informational meetings with representatives of Innovation, Science and Economic Development Canada, and CFI. A major high-level event followed in February 2017, when ESS was the site of a roundtable discussion featuring King Carl XVI Gustaf of Sweden, the Governor General of Canada, David Johnston, and the research ministers of the two nations. The focus was on collaboration between Canada’s and Sweden’s science, industry and research infrastructures. The event also included side science and ministerial meetings with participants from both countries and ESS.

China

The European Spallation Source had the pleasure of hosting Prof. Guoqing Xiao and Prof. Lei Yang of the Chinese Academy of Sciences in December 2015. Following their visit, ESS Technical Director Roland Garoby travelled to China and signed Memoranda of Understanding with two institutes at the Chinese Academy of Sciences, i.e. the Institute of High Energy Physics (IHEP), and the Institute of Modern Physics (IMP). Within the framework of these agreements, China and ESS intend to strengthen collaboration in research and development, and increase the mobility of researchers. The seminar in Lund in May 2016, during which Mr. Guoping Wang of the China Spallation Neutron Source (CSNS) presented status-update on the CSNS project design and instruments, attracted great interest from the ESS Accelerator Division.

India

In November 2016, ESS participated in the 6th Conference on Neutron Scattering (CNS2016) at the Bhabha Atomic Research Centre (BARC) in Mumbai, which brought together more than 100 international and Indian scientists. The audience had the possibility to learn about future science at ESS. Collaboration opportunities between India and ESS were further explored during a visit of the Swedish Minister of Higher Education and Research to New Delhi in January 2017.

Japan

The European Spallation Source together with the Japan Proton Accelerator Research Complex (J- PARC) organised a bilateral workshop in Tokai in June 2016 to strengthen cooperation between Japanese scientists and ESS. Similar collaborative meetings have been scheduled for 2017. In January 2017, ESS hosted Naohito Saito, the Director of J-PARC to plan a joint workshop for ESS and J-PARC, which will take place in the summer of 2017. Both organisations will benefit from a broader Swedish- Japanese project MIRAI that aims to connect universities and academics from both countries through research, education and innovation. The project also strives to attract junior researchers who are in the early stage of their careers in order to maximise the future use of large-scale research facilities such as ESS and J-PARC in both countries. The European Spallation Source and J-PARC are currently preparing a new Agreement of Collaboration in the field of spallation neutron source development.

Russia

The European Spallation Source has established contacts with research institutes in Russia through the EU-funded project CREMLIN that aims to enhance scientific cooperation and the establishment of enduring networks between European and Russian research infrastructures. Within the framework of the project, in June 2016 ESS hosted a workshop on internationalisation, which is a key strategic issue in the process of building, operating and scientifically exploiting large-scale research infrastructures. The topics explored during the workshop were of high relevance for the overall objective of the GSO. The European Spallation Source is also actively involved a German-Swedish- Russian initiative to promote materials science among young scientists through annual RACIRI Summer Schools. The summer school of 2017 will be hosted in Lund. In addition,

ESS together with the CREMLIN project Partners will organise an Innovation Workshop in fall 2017.

KEY ISSUES IN INTERNATIONAL COLLABORATION

The European Spallation Source ERIC Statutes currently do not foresee that after the initial three years, some Observers might not – for various internal reasons – wish to become full Members (or cannot achieve this status within the given timeframe), but who would still like to be part of the international ESS collaboration. Any extension of the Observer-period for a single Observer from three years to a longer period could potentially have a precedent, or a ‘knock-on’ effect on the timetable or momentum in other countries to become full Member. A ‘forced’ exit after three years as Observer is not in line with ESS’s vision of becoming a global – open – neutrons research facility. As mentioned earlier, ESS is currently working on identifying new categories of membership, which would provide for additional forms of collaboration between ESS and national states than currently allowed by the Statutes.

Another important issue is that, in a global context outside the ERA, some Members may have political and legal barriers to join ESS as full Members as outlined in the Statutes and foreseen in the ERIC regulation. It may happen that some potential Members are not willing to meet all the criteria in terms of recognition of European bodies. This may require a type of ‘contractual membership’ that outlines rights and responsibilities in a specific agreement.

These observations lead to the proposition that possibly new category of membership could be introduced; a category between Observer and Founding Member called ‘Associate Member’, or a category that would open up the opportunity for non-member countries, university consortiums or industry to sign agreements for the use of the facility. Both concepts are used in other large-scale infrastructures. The duration of Associate Membership could either be indefinite or

an extended fixed period, after which participation by the national state in ESS is re-assessed based on ESS’s needs and the national state’s scientific and budgetary agendas. It remains to be defined. Associate Membership is not foreseen in the European Spallation Source ERIC Statutes, but it is a well-known concept in several other organisations, albeit sometimes using different titles. However, a first analysis of the difference between the various categories at these other organisations does not show a clear demarcation of benefits versus obligations. This is a risk in that it might appear that Associate membership is nothing more but a ‘polite side-tracking’ of a national state. The risks are related to a possible reduced political and financial endorsement by national policy-makers and/or reduced interest from the scientific community scientific interest inside the country itself. To avoid this risk, it is important to establish clear benefits of being an Associate Member above the Observer-status, whilst still showing there is added benefit of becoming a full Member in due time.

The GSO framework complements the stand-alone efforts of ESS aimed at enlarging its membership base. The framework has helped to strengthen the foundation of strategic partnerships for an increased international scientific collaboration. As a research facility that is physically based in Europe, ESS has naturally built strong relations with European countries. In this respect, the broadly international character of the GSO framework has played a key role in supporting ESS in the process of establishing contacts with stakeholders outside the boundaries of Europe. Despite the rather short period of ESS’ involvement in GSO, the framework has already proved to be helpful in opening avenues for strategic dialogues with partners worldwide. Despite the wide support that GSO enjoys on the highest political level, the framework has not been able to reach its full potential due to limited commitment and lack of response from officers who are directly responsible for facilitating cross-border collaborations at the respective national entities. A more pro-active attitude on the side of all involved parties would contribute to the overall strengthening of the framework in the future.

Alignment of ESS Case Study with GSO Framework Criteria

The European Spallation Source aligns with the criteria set out in the GSO Framework in the following way:

1. Core purpose of global research infrastructures

The European Spallation Source will offer unprecedented capabilities for interdisciplinary research in materials and life sciences. Experiments performed using the instruments at ESS will increase our understanding of the structure and dynamics of materials, resulting in new and environmentally friendly manufacturing processes and products, new and better drugs, faster computers, healthier food and many more advances across a diverse range of science and engineering disciplines.

2. Defining project partnerships for effective management

In 2015 ESS changed its legal status and became a European Research Infrastructure Consortium (ERIC). The European Spallation Source ERIC is governed by Statutes adopted by its Member Countries, which concern governance and operational guidelines, membership, funding, and contribution to the organization, as well as the rights and obligations of the Members. The organization has adopted its own procurement rules, based on transparency, non-discrimination, and competition. The European Spallation Source intends on expanding the current membership base. The Statutes currently allow two forms of collaboration between ESS and national states and their respective research institutes and industrial research facilities: Founding Member and Observer.

3. Defining scope, schedule, and cost

In 2014, a groundbreaking event took place to signal the official start of the construction for the European Spallation Source. The European Spallation Source will deliver its first protons to a solid, rotating tungsten target in 2019, which will in turn generate neutrons for delivery to an initial suite of seven neutron scattering research instruments. The European Spallation Source will reach its full design specifications in 2025, with a suite of 22 public research instruments. In 2013 ESS drafted a Cost Book to provide information to its partners and potential partners about the various types of work available, and the associated cost, and to support discussions about in-kind agreements. The cost capped ESS budget is 1,843 billion euro. The technical scope of the project was outlined in Technical Design Report, which was published in 2013.

4. Project management

The European Spallation Source ERIC is governed by the European Spallation Source ERIC Council, which is bound by the Statutes ratified by the ERIC Member Countries. The Council leadership was appointed, and the Council Rules of Procedure and the Terms of Reference for all advisory committees were adopted.

5. Funding management

As host countries, Sweden and Denmark contribute cash towards 47.5% of the construction cost. Members cover the remaining costs with a ratio of in-kind and cash set at 70:30. To this day, ESS has identified in-kind partners for as much as 544,9 million euro of the total of 675 million euro in-kind contributions within the ESS budget.

6. Periodic reviews

The European Spallation Source has established a process that helps to provide an objective critique and targeted expert advice to deliver the ESS facility. Every year, ESS hosts an external international panel of more than 30 experts to reflect on the progress and give feedback on the project's goals and challenges moving forward. The Annual Review focuses on technical, scientific, managerial and financial aspects of the ESS project. The open dialogue with partners and transparency about the project status and performance help to address issues quickly and keep construction moving forward according to plans. When the Annual Review Committee submits a final written report, the ESS management prepares a list of actions to follow-up on the feedback.

7. Termination of decommissioning

In accordance with Article 5.3.(b) of the European Spallation Source ERIC Statutes "each member shall contribute to the operating costs as provided for in Article 18 and to the decommissioning costs as provided for in Article 19", which are estimated at 177 million euro. Article 19 states that "the members shall share the relevant decommissioning costs, [...] which shall not exceed an amount equivalent to three annual operation budgets, based on the average of the last five years of cost of operation".

8. Access based on merit review

The ESS Intellectual Property Rights Policy is currently under preparation. Article 17 of the European Spallation Source ERIC

Statutes states that the facility should provide access for European as well as international (meaning: non-European) researchers and other users. It also says that the facility will be open for access to other than Members. A more detailed access policy is anticipated closer to the operations phase. Being a Member provides added value in addition to 'excellence based access' in that Members jointly decide in the governing Council on – among other things - budget, the medium-term scientific programme, and the policy for the allocation of and access to beam time, and innovation activities. Scientists from non-Member States will be able to compete for the remaining beam-time based on a competitive peer-assessment, but not access to the decision-making bodies of ESS.

9. E-infrastructure

The ESS Data Policy, currently under preparation, will cover the collection, access, use, disposal and storage of scientific research data collected from the neutron beam instruments located at ESS. In August 2016, ESS opened the offices of its Data Management and Software Centre in Copenhagen, a key driver in achieving an optimal data processing speed that will allow ESS to stream raw data from experiments carried out in Lund, process it, and return meaningful and scientifically valid data back to its users.

10. Data exchange

Article 21.3. of the European Spallation Source ERIC Statutes states: "In general open access shall be favoured for data collected as a result of the use of the ESS facility [...]" According to Article 21.4. of the Statutes, "The Organisation shall adopt its own data and intellectual property rights policy." As a research facility under construction, ESS does not yet produce data and its Data Policy has not yet been adopted. However, in line with the Statutes, ESS Data Policy is under preparation and is expected to be submitted for the approval of the Council in one of its upcoming meetings. The Data Policy will cover the collection, access, use, disposal and storage of scientific research data collected from the neutron beam instruments located at ESS under the following modes of access: Peer Reviewed Access, Quick Access, and Facility Time. The procedures that will be implemented will be in line with the European Union standards.

11. Clustering of research infrastructures

The European Spallation Source is involved in a number of projects funded by regional and national grants. The projects aim to foster innovation and strengthen collaboration between research infrastructures, academia and industry. Under the framework "Horizon 2020", and "The 7th Framework Programme for Research and Technological Development (FP7)" of the European Commission, ESS is currently involved in projects such as SINE2020 and NMI3, which are dedicated to neutron facilities.

12. International mobility

The European Spallation Source brings together more than 40 in-kind partners, nearly 100 collaboration partners and staff from 47 different countries. The diversity in partners enables a broad network for the exchange of best practices and enhances mobility of staff and knowledge. Some ESS Member Countries will provide their in-kind contribution in the form of actual equipment to be transferred

to ESS. Other countries, will deliver the in-kind contribution primarily in the form of manpower during the construction of ESS in Lund and the installation/integration of the various instruments. Swedish authorities maintain a strict taxation regime for anyone working in Sweden, even for a short period of time. A practical problem facing ESS is that the current situation might prevent some researchers in Member Countries to consider spending their time on ESS construction/integration and later standard operations, if this would affect their tax situation relative to the income they receive. It may also affect their situation relative to their pension, social security benefits, or specific tax benefits. This problem may lead to costly delays in the construction of ESS. The goal for ESS is therefore that In-Kind Staff should not be taxed in Sweden; they should maintain their fiscal residence in their home country.

13. Technology transfer and intellectual property

The European Spallation Source is building capacity in technology transfer together with the Danish Technical University and other partners within the framework of the EU-funded BrightnESS project. Whilst ESS is working closely to learn from the experience of other research infrastructures, developing a policy based open innovation and collaboration.

14. Monitoring socio-economic impact

The European Spallation Source embraces the Open Innovation paradigm and encourages the exploitation and dissemination of innovation created from using ESS facilities and/or ESS staff for new markets outside the primary intended use. Already in its construction phase ESS is actively working toward defining the indicators and metrics through which it will be able to measure its own contribution toward increasing scientific knowledge and technological solutions toward societal challenges. One example is the ESS H2020 "BrightnESS" project, which is in the process of defining indicators on knowledge transfer and job creation during the so-called In-Kind collaborations between ESS, scientific institutes in its Member Countries and industrial partners. BrightnESS will also measure the effects of the ESS collaboration on participation by 'Low research-performing countries' (LRPC) in neutrons research, which is an indicator for strengthening of the overall European Research Area. The project will also monitor capacity building and Research Infrastructure human capital development in targeted/relevant regions as a result of ESS construction, by measuring research staffing at institutes in existing as well as prospective/new ESS Member Countries.

CANADIAN HIGH ARCTIC RESEARCH STATION

Progress Report on CHARS Case Study

Prepared for the Group of Senior Officials on Global Research Infrastructures

Executive Summary

The **Canadian High Arctic Research Station-CHARS** is an example of a new federally-funded and federally-owned research station in an area of global relevance and interest. The location of the CHARS campus is significant, since it is already experiencing significant effects of climate change and it is adjacent to areas with a high potential for resource development.

Work on the CHARS campus began in 2014, and the station is expected to be fully operational in fall 2017. Once complete, the CHARS campus will serve as the headquarters of Polar Knowledge Canada (POLAR), a recently-formed Government of Canada agency. The fully operational research campus will provide a broad range of services, including a technology development centre, mechanical and electrical workshops, a knowledge-sharing centre, and advanced laboratories. It is anticipated that approximately 40 full time resident staff will be employed at the station in science and technology, knowledge management, lab management, facilities management, and general administration. It is also estimated that CHARS could host an additional 100 visitors during the summer, which is the peak research season, and a smaller number of visiting users the rest of the year.

International partners will be able to use the CHARS campus and monitoring infrastructure for their own research on a cost-shared basis (through in-kind support). POLAR does not have a membership model for use of the CHARS campus as the infrastructure is fully funded and owned by the Government of Canada. In the future, international

partners could be involved in expanding the infrastructure on the CHARS campus. However, to date, international partners have not contributed financially to construction and operations.

POLAR participates in a number of multilateral scientific and research organizations, including the International Arctic Science Committee and the Scientific Committee on Antarctic Research. POLAR is also Canada's competent national authority for the Arctic Council Agreement, Enhancing International Arctic Scientific Cooperation, signed in May 2017. Moreover, POLAR engages with other international Research Infrastructures that are part of the International Network for Terrestrial Research and Monitoring in the Arctic and the Circumpolar Biodiversity Monitoring Program. POLAR has also signed letters or memoranda of understanding with organizations in Iceland, Japan and Korea.

Since POLAR is a relatively new agency, policies are still being developed and implemented. The alignment of these policies with the Group of Senior Officials (GSO) Framework criteria will continue to evolve. Because the facility is owned and operated by the Government of Canada, international partners have not been critical for the development of the CHARS campus to this stage. However, international partners will be instrumental in POLAR's delivery of its science and technology program. Going forward, the guidance provided by the GSO, along with the partnerships it can facilitate, will be important to POLAR, as the CHARS campus develops into a Global Research Infrastructure.

Introduction

Polar Knowledge Canada (POLAR) is a Government of Canada agency that was established on June 1st, 2015 and is headquartered in Cambridge Bay, Nunavut. POLAR's mandate is to advance Canada's knowledge of the Arctic and strengthen Canadian leadership in polar science and technology (S&T). POLAR consists of a pan-northern S&T program, a knowledge management and engagement team, and the Canadian High Arctic Research Station (CHARS) campus in Cambridge Bay.

Construction of the CHARS campus began in August 2014 and it is expected to be operational in fall 2017. Once completed, CHARS will be a year-round world-class S&T facility in Canada's North that

complements the network of research facilities that already exist in the Canadian North and internationally. The CHARS campus will provide a suite of services including advanced laboratories, a technology development centre, mechanical and electrical workshops, and a knowledge-sharing centre.

POLAR is currently 2.5 years into its 5-year initial S&T program. The S&T program has four science priority areas, in addition to its flagship project known as the CHARS Experimental and Reference Area (ERA), located in and around Cambridge Bay. The four science priority areas are:

- Alternative and renewable energy for the North.
- Baseline information to prepare for northern sustainability.
- Predicting the impacts of changing ice, permafrost, and snow on shipping, infrastructure and communities.
- Catalysing improved design, construction and maintenance of northern-built infrastructure.

The science priority areas have a pan-Arctic focus, while the ERA program is an integrated research and monitoring site centred on the CHARS campus in Cambridge Bay; a long-term project designed to unify the different elements of POLAR's pan-Arctic S&T program. The ERA program features environmental research and monitoring of terrestrial and marine valued ecosystem components (VECs), and includes intensive monitoring areas that examine the ecological drivers of change. Information is framed in a social-ecological model, and data collected within the ERA will be scaled up geographically.

POLAR is also a funder of Canadian Arctic science through its Grants and Contributions programs. Grants and contributions are not open to international researchers, although international researchers could potentially be part of a Canadian project receiving funding. POLAR strives to support projects that demonstrate scientific excellence while also ensuring strong community and Indigenous involvement.

Cambridge Bay, Nunavut, is a growing community of 1600 people with a viable commercial sector that provides reliable access to general supplies, accommodation, vehicle rental and telecommunications. First Air and Canadian North airlines provide daily direct flights between Cambridge Bay and Yellowknife, Northwest Territories, which is the gateway to Canada's western Arctic.

The CHARS campus will have office and laboratory space to host about 30 medium-term visitors. Transient users passing through to field sites are expected to peak at 100 users per day during the summer. POLAR staff will provide general logistics support for scientists going into the field and working in the research labs. Air charters, all-terrain vehicles, small boats, snowmobiles and camping equipment are provided by the Government of Canada's Department of Natural Resources' Polar Continental Shelf Program.

The region in which the station is located is already experiencing significant climate change and the Canadian Arctic is an area of high potential for resource development. As long-term monitoring and baseline studies of Arctic ecosystems and communities are put into place, the station will become increasingly a strategic location for understanding climate change and how to mitigate and adapt to its impacts. The Canadian Arctic is unparalleled in the diversity and extent of its ecosystems and the CHARS campus is located in the centre of this unique "natural laboratory."

Expansion of International Research Partnerships

The CHARS campus' infrastructure and cross-cutting capabilities will provide a platform and resources to engage potential collaborators around targeted S&T priorities as defined in POLAR's S&T program. Recognizing the multiplicity of stakeholders that need to be engaged to address Arctic and climate issues effectively, the CHARS campus is being designed to support partnerships and collaborations. Its campus-like environment will provide opportunities to share information among researchers, and it will serve as a repository of data and research conducted in the region.

The station will link relevant industry, academic, Indigenous, government, and international stakeholders and leverage their expertise, experience, and resources to address shared goals. International partners will be able to use the CHARS campus and monitoring infrastructure for their own research on a cost-shared basis (through in-kind support).

POLAR does not have a membership model for the use of the CHARS campus at this point, as the infrastructure is fully funded and owned by the Government of Canada. The Department of Indigenous and Northern Affairs Canada (INAC) is leading construction of the CHARS campus, which will become a POLAR asset upon completion in 2017-18. POLAR reports to the Minister of INAC and is led by a nine-member Board of Directors responsible for operational planning and budget oversight, and a President, who is responsible to the Board

for the agency's day-to-day operations. In the future, international partners could be involved in expanding the infrastructure on the CHARS campus, including new monitoring equipment. However, to date, international partners have not contributed financially to the construction and operation of the CHARS campus.

POLAR is a key point of contact in Canada for the international polar research community and is looking to strengthen connections internationally through letters or memoranda of understanding (LoU/MoU) and project-specific agreements that leverage additional capacity and support the next generation of polar researchers. POLAR engages with other international research infrastructures as a member of the International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT), the Circumpolar Biodiversity Monitoring Program (CBMP), and the Canadian Network of Northern Research Operators (CNNRO). In particular, POLAR is developing an integrated research and monitoring program that is very synergistic with INTERACT in terms of science themes and approaches. To strengthen these initial ties, POLAR would welcome involvement in future INTERACT meetings.

POLAR is also Canada's adhering body to the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR). In addition, POLAR is Canada's National Contact Point for Arctic/polar research for the European Union's Horizon

2020 Arctic dimension program. POLAR's President and CEO, David J. Scott, led the Canadian delegation to the Arctic Council's Scientific Cooperation Task Force (2015-2017). POLAR also attends and participates in various international events, working groups and

organizations to further advance its S&T program and to identify opportunities for collaboration with international partners at the CHARS campus.

Initiated and Established Partner Contacts

POLAR welcomes international and domestic researchers from government departments, academia, non-governmental organizations, and the private sector to conduct scientific research and test innovative technology at the CHARS campus. There are opportunities for doing research at the CHARS campus with or without formal agreements (e.g. LoU/MoU). The typical process to establish a formal agreement includes initial discussions focusing on broader collaboration, follow-up discussions regarding specific areas of mutual interest, development and implementation of the collaboration mechanism, and planning leading to the start of the research activities. Timelines to establish collaboration mechanisms vary depending on the level of scientific collaboration needed, geographic scope, funding, etc.

A number of countries and facilities have been formally involved with POLAR to date. These include:

- **Japan** (National Institute of Polar Research - NIPR): POLAR and NIPR signed a LoU concerning polar science cooperation on June 6, 2016.
- **Republic of Korea** (Korea Polar Research Institute - KOPRI): POLAR and KOPRI signed a MoU in October 2015, detailing specific areas and activities in which to deepen research collaboration.
- **United States** (National Aeronautical and Space Administration - NASA): On June 16, POLAR and NASA signed an agreement to coordinate environmental research and monitoring activities in the western Canadian Arctic. This ensures close alignment of NASA's Arctic Boreal Vulnerability Experiment (ABoVE) with POLAR's planned science activities in this region.

- **France** (Centre National de la Recherche Scientifique - CNRS): The former Canadian Polar Commission (now POLAR) and CNRS signed a Letter of Agreement in November 2014.

- **Italy** (Consiglio Nazionale delle Ricerche - CNR): The former Canadian Polar Commission (now POLAR) and CNR signed a MoU in October 2014. CNR staff visited Cambridge Bay in summer 2016 to explore the possibility of deploying upper atmosphere observation systems in Cambridge Bay.

- **Iceland** (Icelandic Arctic Cooperation Network - IACN): POLAR and IACN signed a LoU on June 11, 2016 to encourage and coordinate Arctic research between the two countries.

These partnership/collaboration arrangements establish parameters for collaboration, including research areas, project coordination, roles of each partner, open data, logistical support and reporting and publication. These parameters are consistent with POLAR's organizational policies and priorities related to S&T research and open data.

Going forward, POLAR has expressed interest in learning more about potential opportunities for collaboration with the following research infrastructures/organizations through the GSO: Ocean Observatories Initiative (OOI); National Ecological Observatory Network (NEON); and Deep Sea Scientific Drilling Vessel (CHIKYU). POLAR also plans to pursue discussions with Svalbard Integrated Arctic Observation System (SIOS), which had made contact with POLAR through the GSO.

Key Issues in the Development of Partnerships

In developing partnership/collaboration arrangements, POLAR has encountered the following issues:

- **Language barrier:** Developing a partnership/collaboration arrangement is more complicated when the partners do not speak the same first language. POLAR addressed this challenge by working with intermediaries such as the Canadian Embassy staff in this specific country. The arrangements were also reviewed and translated in each partner's first language.
- **Specificity of projects:** Partnership/collaboration arrangements may not be as successful and efficient if project-specific activities are

not identified. POLAR addressed this issue by having scientists from POLAR and partner organizations identify key areas of interest and project-specific initiatives.

- **Political barrier:** Countries' national and foreign policies have an influence on the development of partnerships/collaboration and can even be a barrier, in some instances. POLAR consults with Global Affairs Canada (Department of Foreign Affairs) before developing collaboration mechanisms (e.g. LoU/MoU).

- **Legal barrier:** Countries each have their own legal requirements and need to arrive at a consensus when developing a collaboration

mechanism. This can become a barrier if partners cannot agree on legal requirements.

- **Transition barrier:** POLAR is a relatively new Government of Canada agency and is in the process of transitioning its staff to Cambridge

Bay. The CHARS campus is also not operational yet. The transition of human resources and the construction of the CHARS campus are factors that complicate the development of partnerships/collaborations.

Data Management

POLAR supports the long-term preservation of and access to polar research data. Currently, the Polar Data Catalogue (PDC, www.polardata.ca) is the primary and default repository for POLAR metadata and data. The PDC provides data management services that include stewardship, preservation and free and open dissemination of POLAR's data and information.

All internal science metadata and data produced by POLAR is available through the PDC. All metadata produced through partnered research (POLAR-supported projects), will also be available through the PDC. Partnered data sets may also be stored at PDC or any compliant data servers that allows open access. POLAR encourages all partners involved in collaborative research to make their data open and accessible through standardized services. POLAR has recently partnered with other Government of Canada government programs to produce common Data Principles and Guidelines in order to create consistency among many of the programs. This helps researchers that are funded by multiple programs to reduce the reporting and compliance requirements and ensures consistent data management practices. Data produced in association with POLAR must be open and freely accessible to the public, with the exception of secure data and data that poses a risk to local knowledge holders.

With respect to the GSO five open data principles:

1. Discoverable – Metadata conform to ISO 19115 geographic metadata standard. PDC, on behalf of POLAR, has registered Digital Object Identifiers (DOIs) to each dataset.

2. Accessible – Before users can access the PDC Search application they must agree to the Terms of Use. For datasets that have restricted use, the metadata description is available but it indicates that the dataset is not publicly available. Contact information is provided to the user. The Data Manager can adjust the restrictions on datasets as needed.

3. Understandable – All datasets archived in the PDC are linked to metadata, which is a detailed description of the data. Contact information is provided in the metadata file in the event the user desires more information about the data. The PDC has a number of online data visualizations that are intuitive and easy to understand, such as snow water equivalent (SWE) maps, sea ice thicknesses, and lake ice cover.

4. Manageable – POLAR has a Data Principles and Guidelines document.

5. People – Before it is made available online, all metadata and data submitted to the PDC are thoroughly examined by a qualified Data Manager on staff.

A POLAR Interim Data Policy took effect in 2016. The final Data Principles and Guidelines document is available as of April 2017. Intellectual property issues have not been addressed yet.

Private Sector Innovation

The CHARS campus will serve as a major hub for Arctic technology development and innovation by providing a research platform, expertise, infrastructure and support to northern entrepreneurs and innovators in developing, adapting, and testing technologies that could be used in the North, including the 'northernization' of southern-based technologies. Along with its research labs, the CHARS campus will include a technology development centre to promote the translation of knowledge into innovation and serve as a link to the private sector.

To support the private sector and catalyze innovation in the development of the CHARS infrastructure, a construction

management approach was used to overlap the design and construction phases. This innovative approach not only allowed construction to begin as the design progressed, but also allowed the construction manager to promote smaller packages of work, making them more accessible to local companies and trades to encourage local skills development and to provide opportunities to Land Claim beneficiaries through Inuit Benefits Plans.

Alignment of CHARS Case Study with GSO Framework Criteria

POLAR is a relatively new organization (it came into force on June 1, 2015), and therefore policies are still being developed and implemented as is the research direction for its S&T program. As such, it is expected that the alignment of the CHARS case study with the GSO Framework criteria will continue to evolve as POLAR matures as an organization. With respect to each criteria:

1. Core purpose of global research infrastructures

The CHARS campus addresses a pressing global research challenge (i.e., climate change). As noted above, the CHARS campus is located in a region already experiencing significant climate change and high resource development potential. The location of the campus is therefore very strategic for understanding climate change, its impacts and how to mitigate and adapt to these changes.

2. Defining project partnerships for effective management

Roles and responsibilities of partners will vary based on the nature of the project and will be defined in the collaboration mechanism (e.g. LoU/MoU) between POLAR and that specific partner. Given that POLAR is a relatively new agency and that the CHARS campus is not operational yet, POLAR has had limited on-the-ground collaborative projects in Cambridge Bay to date and cannot provide concrete examples at this time.

3. Defining scope, schedule, and cost

Scope, schedule and cost will be defined at the early stage and will be included in the collaboration mechanism (e.g. LoU/MoU). The value of in-kind contributions will also be identified. For example, POLAR can provide accommodation to partners in Cambridge Bay, which will be identified as in-kind contributions. Partners typically would pay for vehicles, local guides, meals, transport of equipment, etc.

4. Project management

The CHARS campus is managed by POLAR. POLAR is a Government of Canada agency within the portfolio of the Minister of INAC. As noted above, POLAR is led by a Board of Directors responsible for operational planning and budget oversight, and a President responsible to the Board for the agency's day-to-day operations. International projects are managed on a case-by-case basis and in collaboration with partners.

5. Funding management

CHARS is fully funded by the Government of Canada. Architectural design, construction, equipment, and furniture for CHARS as well as the implementation of the S&T program are valued at about C\$250 million until 2017-2018. The federal department of INAC was responsible for delivering on the architectural design, construction, equipment, and furniture for the station for an expected total of C\$204 million. The remaining C\$46 million for the S&T program's implementation was started by INAC and is now being administered by POLAR. After construction is complete in 2018, C\$26.5 million per year will support the ongoing program and operation of the station through POLAR.

POLAR and its partners will agree on financial and in-kind contributions during the development of the collaboration mechanism. Both financial and in-kind contributions will be included in the collaboration mechanism.

6. Periodic reviews

POLAR intends to develop annual scientific reports and publications to mobilize knowledge being created through its S&T program and POLAR-funded projects. POLAR scientists will also publish scientific articles in peer-reviewed journals.

7. Termination and decommissioning

CHARS is expected to have a life span of at least 75 years, which may be expanded to more than 100 years. No decommissioning planning has been undertaken.

8. Access based on merit review

All projects funded through POLAR's Grants and Contributions program will need to be well-aligned with either POLAR's S&T priorities or Knowledge Management and Engagement activities and will go through a rigorous peer-review process. POLAR has not yet developed an access policy for the CHARS campus; however, it is expected that priority will be given to: 1) organizations that have direct partnerships with POLAR (e.g., through funding agreements or LoU/MoU); 2) organizations that can contribute to one of POLAR's four S&T priorities; and 3) national and international researchers, evaluated on a case-by-case basis in relation to the availability of resources.

9. E-infrastructure

The CHARS campus will offer e-infrastructure capabilities that will allow POLAR to be creative and find ways to mobilize knowledge through web broadcasts, webinars, podcast, etc.

10. Data exchange

A POLAR Data Principles and Guidelines Policy is available to provide direction for all data collected in collaboration with POLAR. This document is an evergreen list of requirements and suggestions, and will be reviewed annually. As part of POLAR's funding requirements, POLAR will require that all of its recipients upload their metadata (and data where applicable) to the PDC.

11. Clustering of research infrastructures

POLAR is a member of CNNRO, which is a network of research support facilities providing specialized technical services and infrastructure to academic, government, private and international scientific research sectors that make research possible in Canada's Arctic and sub-Arctic regions. CNNRO member facilities range from oceanographic research vessels and long-established research institutes and observatories, to seasonal field stations and un-staffed remote monitoring installations. CNNRO members are widespread, representing every major ecological region in Canada's North. However, there is currently no overarching arrangement for researchers to move among these facilities.

12. International mobility

POLAR supports international participation at the CHARS campus. At this time, POLAR has not developed an international mobility program or policy.

13. Technology transfer and intellectual property

The CHARS campus will have technology development space, which will encourage development of new technology and/or

'northernization' of existing technology. Intellectual property issues have not been addressed yet.

14. Monitoring socio-economic impact

N/A

Conclusion

POLAR continues to work toward defining its policies and developing priorities for international partnerships/collaborations. As the infrastructure is at an early stage of development, resources for the CHARS campus have largely focused on constructing the campus. Because the facility is owned and operated by the Government of Canada, international partners have not been critical for the development of the CHARS campus to this stage, although international partners have and will continue to be instrumental in POLAR's delivery of its S&T program.

Going forward, the guidance provided by the GSO, along with the partnerships it can facilitate, will be important to POLAR as the

CHARS campus develops further into a research infrastructure open for global participation. In particular, POLAR sees continued value in the GSO through:

1. Leveraging potential partnerships with GSO member facilities in order to enhance environmental monitoring in the Arctic.
2. Promoting POLAR and its CHARS campus as a key partner for collaborative Arctic scientific research.

Learning best practices regarding developing and implementing policies and guidelines related to global research infrastructures.

